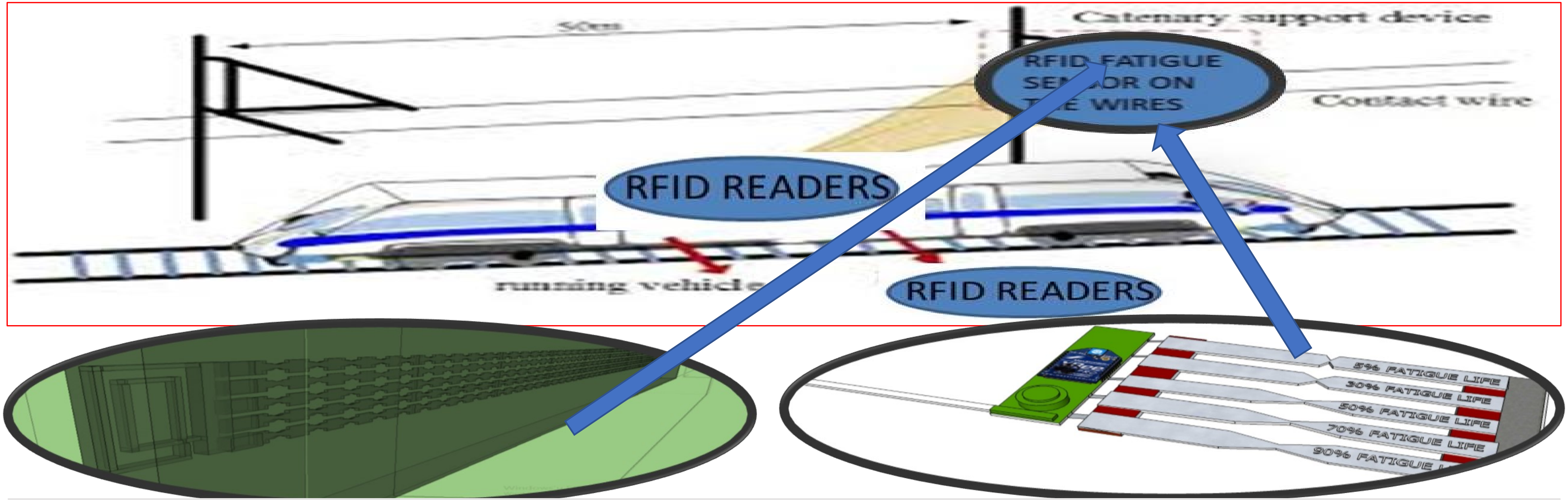
Contact Wire Fatigue Failures UK CASE:

Network Rail (NR) is responsible for 20,000 miles of rail lines in the UK, of which around 40% is electrified. An annotated image of the overhead line environment is included in Figure 1 (see Appendix). The contact wire is designed to conduct electrical energy, trains collect current from the overhead line through a pantograph (see Figure 2).

The passage of trains at speeds of up to 120 mph causes degradation of the contact wire, this process leads to a continual risk of fatigue failure (i.e. complete breakage of the contact wire). In the last year, 6 or 7 failure events have occurred each costing £1M or more in repairs and disruption. The vast majority of failures in the contact wire occur in or around clamped sections due to the increased transverse stress caused by the passage of pantographs, which exert an upward force on the wire to maintain electrical contact.

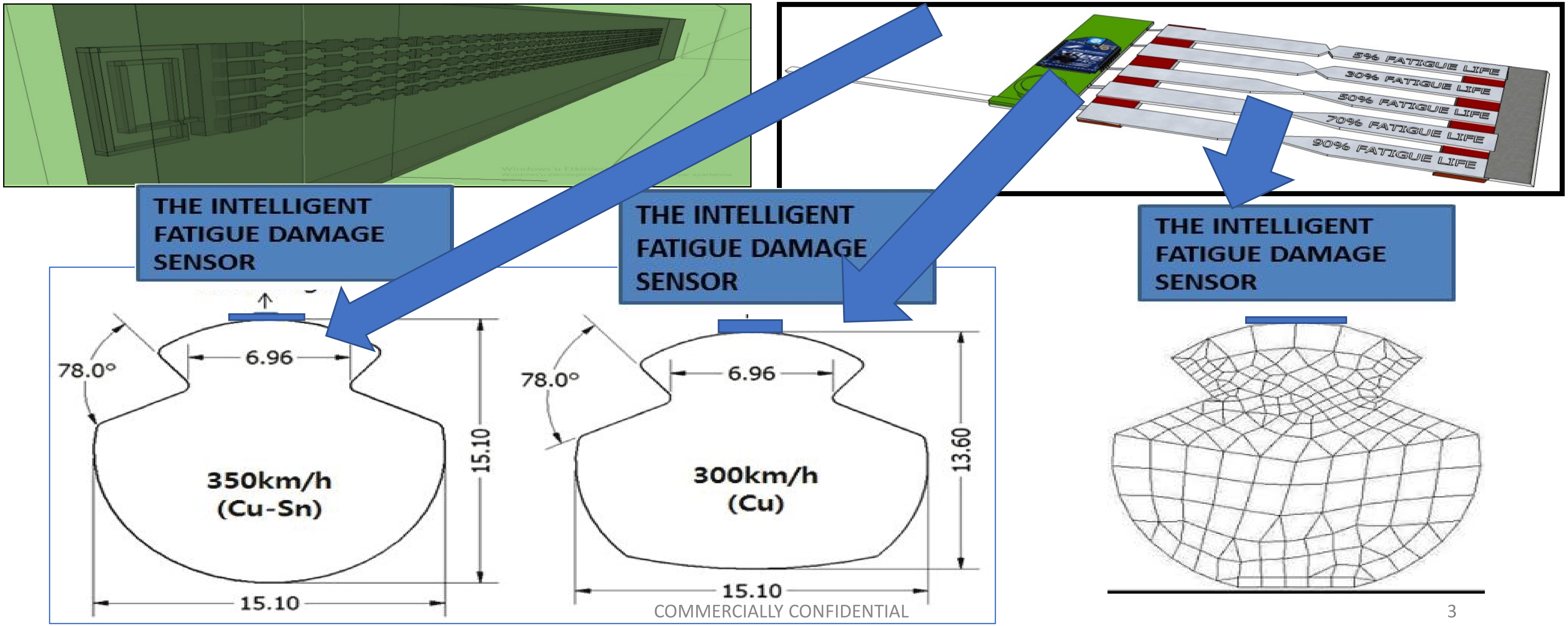
This project aims to reduce the in-operation failure of contact wires, through the accurate identification of defects. If points of potential failure can be identified at an early stage, intervention and preventative maintenance can occur. This will increase the reliability of operations on the UK rail network, reduce maintenance costs, and provide safety benefits. In future, NR also may want to expand the detection capabilities to allow for estimation of the remaining life of the asset, however this may require further study of the deterioration mechanisms beyond the current challenge.

A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System
(PROPOSED SYSTEM MODEL)



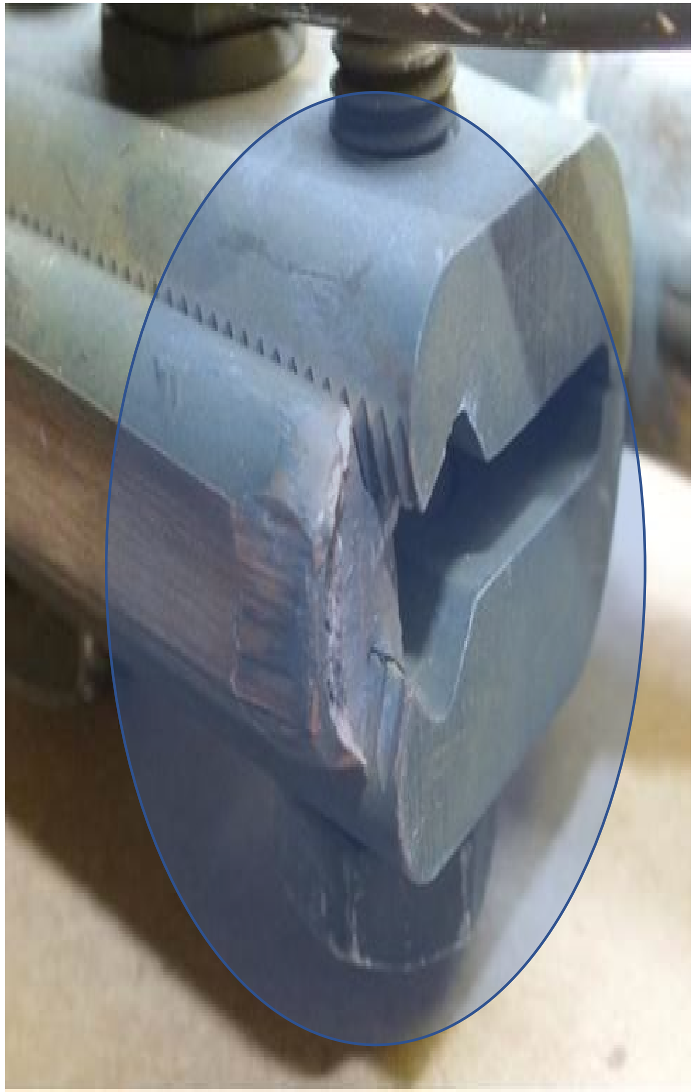
A Novel Smart RFID Fatigue Damage Sensor aiming to the prediction of fatigue residual strength of critical mechanical and structural components for Structural Health Monitoring has been DEVELOPED and PATENTED (PATENT N0. US 8,746,077 B2).

A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System (APPLICATIONS TO CONNECTION WIRES)



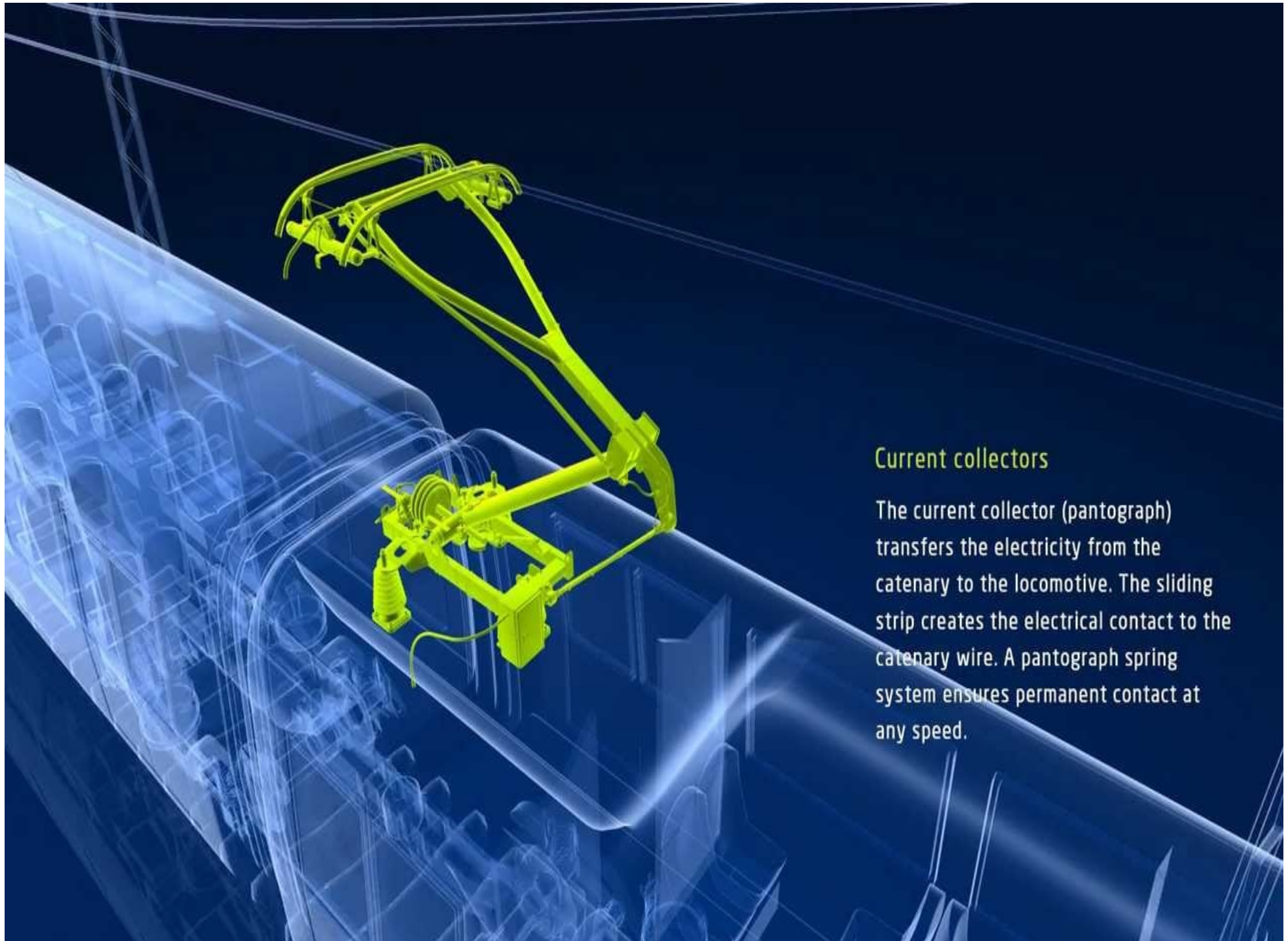
A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **Since carbon emission level of electric railway system is much lower than that of automotive transportation, electric railway system has been known as eco-friendly and low-carbon transportation.**
- **Recently, to expand the use of such railway system, there is global tendency of developing high speed railway system.**
- **In parts of high speed railway system, contact wire which supplies electricity to railway vehicles is exposed to continuous wear and bending fatigue through the contact with pantographs of running railway vehicles. In the past, only wear life of contact wire was considered since it is known that wear life is shorter than fatigue life.**
- **The vast majority of failures in the contact wire occur in or around clamped sections due to the increased transverse stress caused by the passage of pantographs, which exert an upward force on the wire to maintain electrical contact.**



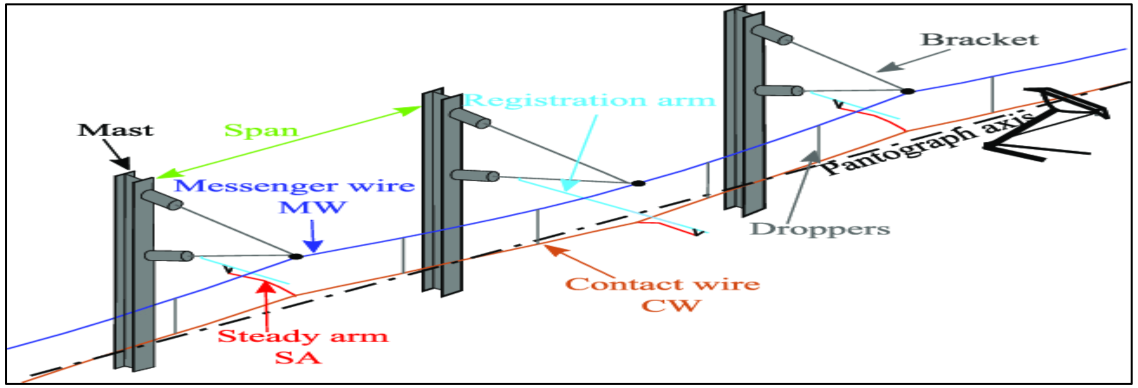
A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

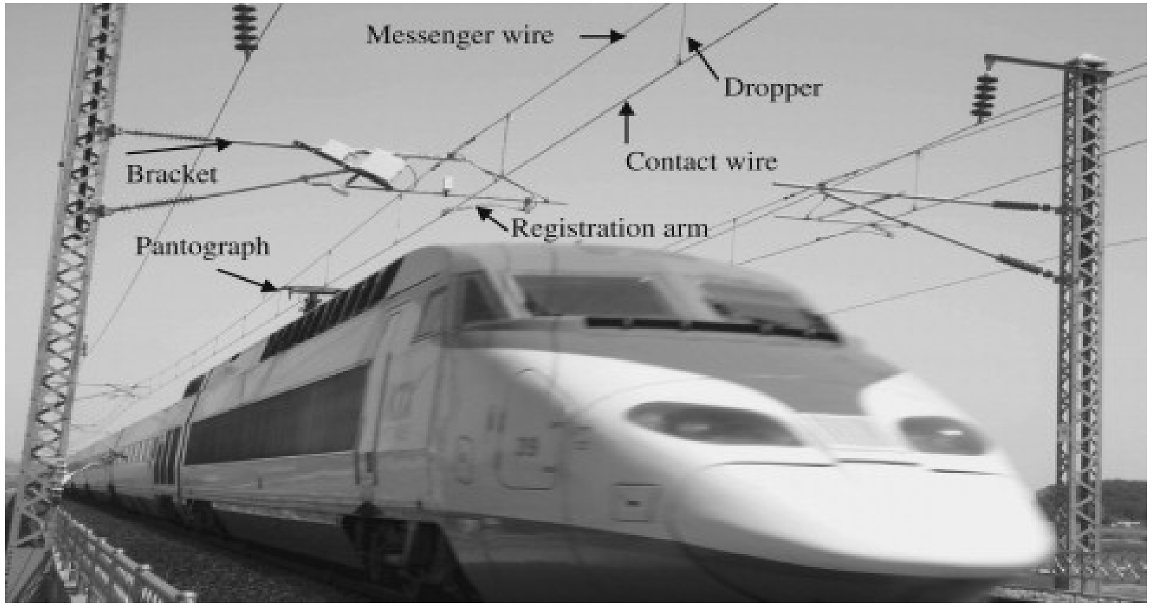
- **The pantograph-catenary system is an important component of the traction power supply system of the high-speed train, as shown in Figure.**
- **Dropper is the support of the whole pantograph-catenary system, and it is the transmitter of vibration and force between messenger wire and contact wire, and the key component of the safety operation of power supply catenary.**



A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **During exploitation of high-speed railway, the cyclic stress appeared in a dropper may cause the fatigue failure of dropper.**
- **It directly leads to failure of train running. At high speed and large traffic density, the failure will cause more frequent interference to the running state of the catenary system.**
- **The cyclic dynamic stress amplitude of dropper is very high, and fatigue damages can be easy to be occurred.**
- **The study of fatigue life of catenary parts such as dropper is important for ensuring the high reliability of pantograph-catenary system and the safe operation of high-speed train.**



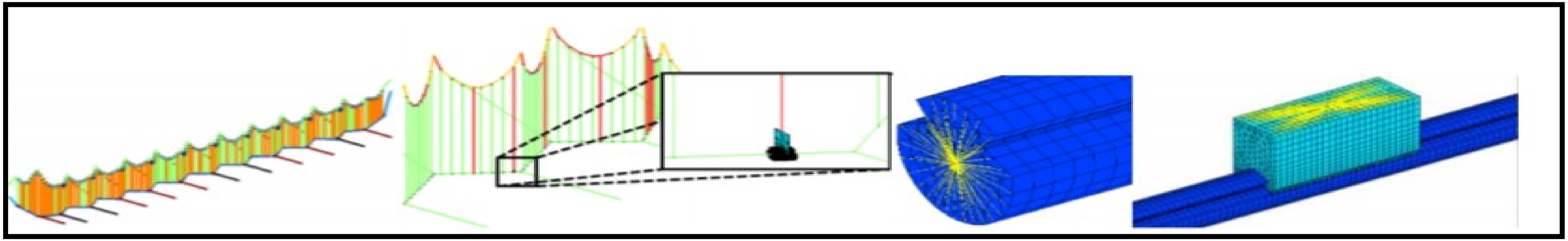


A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **The report of the fatigue failure on contact wire of Shinkansen in Japan, bending fatigue of contact wire has become a very important issue to be considered for the safety of contact wire.**
- **In this paper, based on the fatigue damage evaluation process that Yamashita et al. suggested for pure copper contact wire, cumulative fatigue damage on Cu-Mg contact wire which is newly developed for 400km/h-level railway system was calculated, and fatigue safety factor on Cu-Mg contact wire at allowable strain condition was investigated.**
- **In addition, to simplify such tests, a simpler method to obtain cumulative fatigue damage on contact wire from standard tensile test result is suggested. Contact wire Fatigue Damage Safety factor Allowable strain (Stress)**

A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **The fatigue fracture or failure in the power contact wires of high speed trains is one of the most critical fatigue damage failures occurring on the high speed network because it is undetectable and it has a huge impact on traffic disruption.**
- **The contact wire lifespan of a high speed line is estimated at more than 50 years,**
- **it is necessary to consider the risk of fatigue damage the contact wires due to early fatigue failures the estimated usage lifetime of the contact wires.**
- **The Railway Technical Research Institutes studied this important fatigue damage phenomenon for a long time and performed experimental tests.**
- **Using these results and comparing with fatigue failures occurred, a preliminary analysis is carried out to identify parameters which significant influence the fatigue phenomenon.**

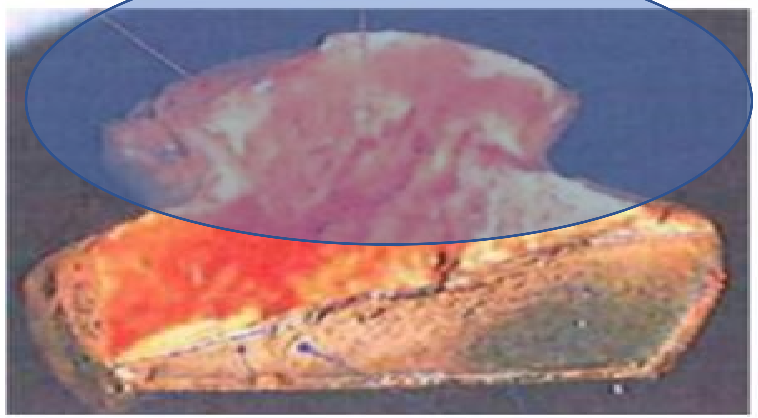


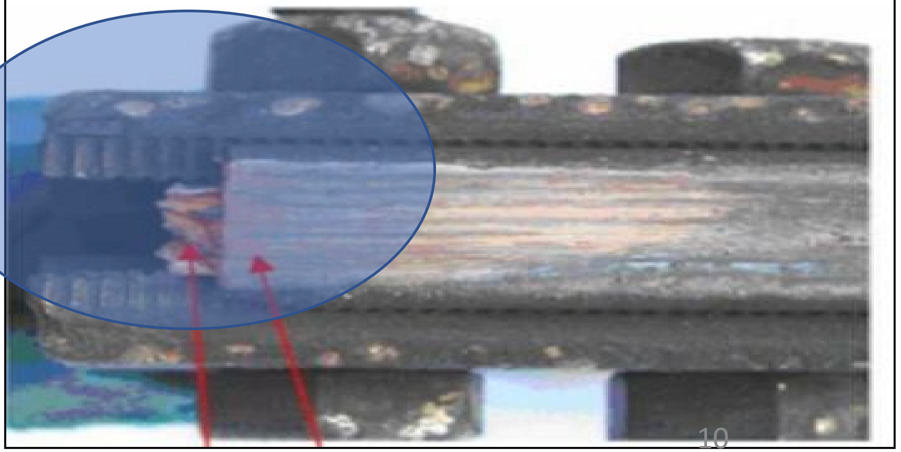
A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **The main criterion used to determine the contact wire replacement of the Overhead Contact Line (OCL) is wear but, on high speed lines, the measured wear rate is very small. In this way, the contact wire lifespan of a high speed line is estimated at more than 50 years and thus it is necessary to consider the risk of having other types of system failure.**
- **The fatigue fracture is one of the most critical failures which may occur on the high speed network because it is undetectable and it has a huge impact on traffic disruption, client discomfort (delays, speed slowdowns) and cost explosion.**
- **Unfortunately, conditions of use increase the risk of fatigue failure: with overloaded traffic, each year more than 220 000 pantographs run under the catenary between Paris and Lyon, the tensile load applied to the contact wire is very high particularly on high speed lines and may increase in the future, the damping ratio of the catenary is so low that a loading cycle is composed of several bending waves preceding and following the pantograph passage, there is a lot of defects in the contact wire surface due to pantograph friction, electrical arcs and corrosion which can cause crack initiation,**

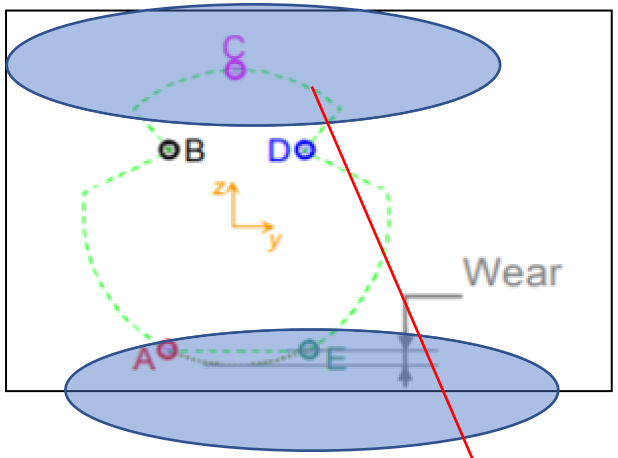
A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

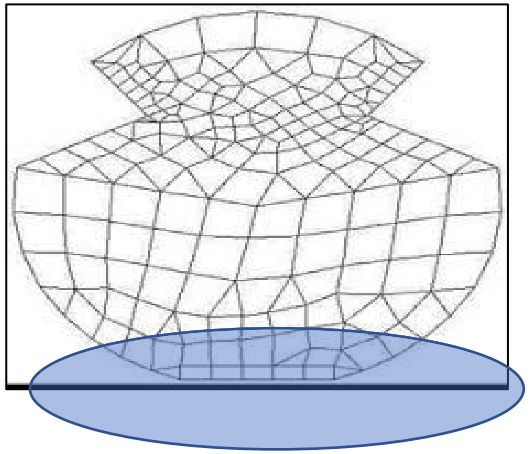
- **In France, some fatigue failures have already occurred on the overhead contact line between Paris and Lyon. This overhead line was replaced after only 29 years of use because fatigue failures took place under the junction claws.**
- **This component, commonly used in maintenance on classical lines, appeared to be inadequate when used on high speed lines. Its heavy weight and its high stiffness produce important dynamic loads and arcing with the pantograph passage.**
- **A modification of the maintenance procedure limits the number of settled claws and their duration, but the fatigue could take place on other lines. Indeed, the French network speed rising tendency requires an increase of the mechanical tension in the contact wire and this parameter heightens the fatigue failure phenomenon.**

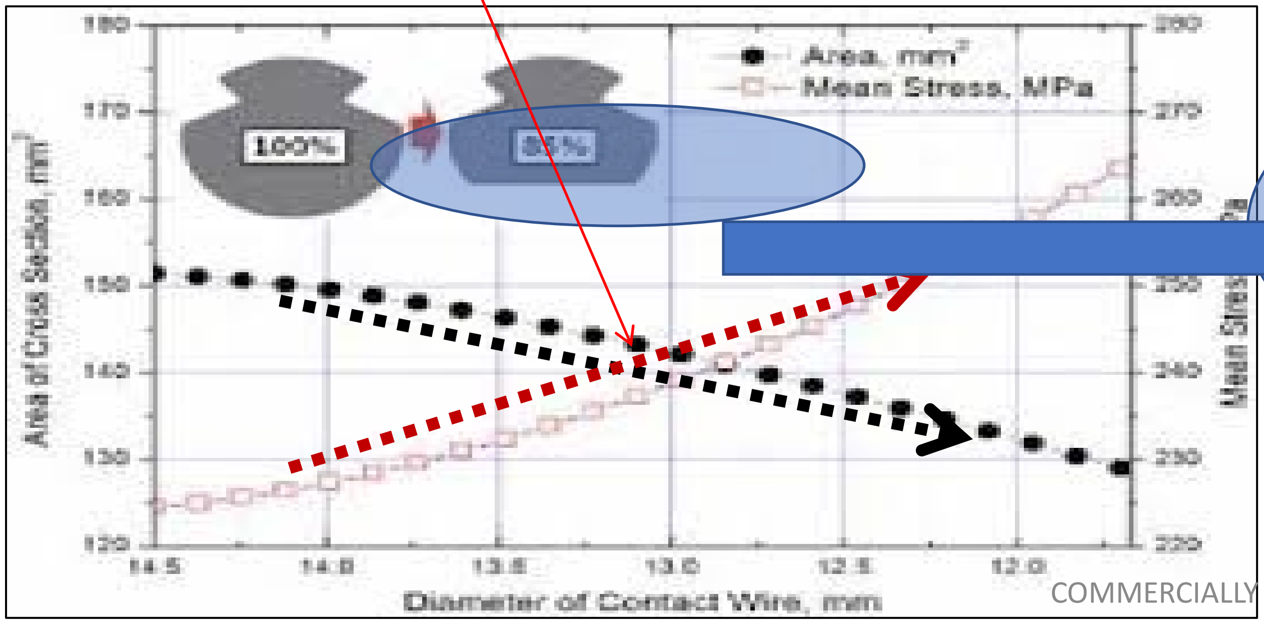




A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System



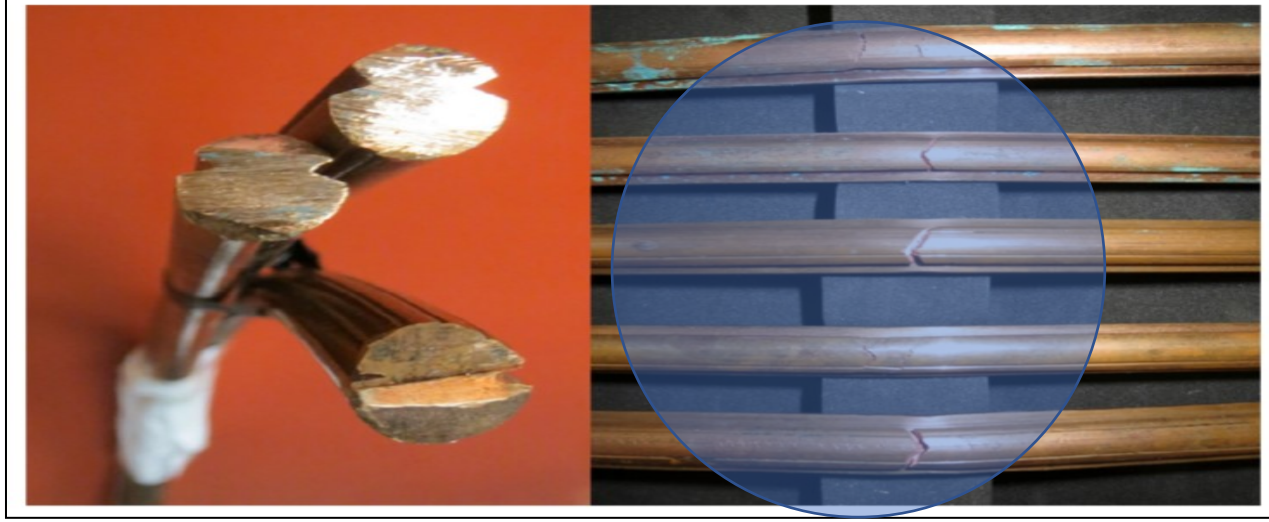


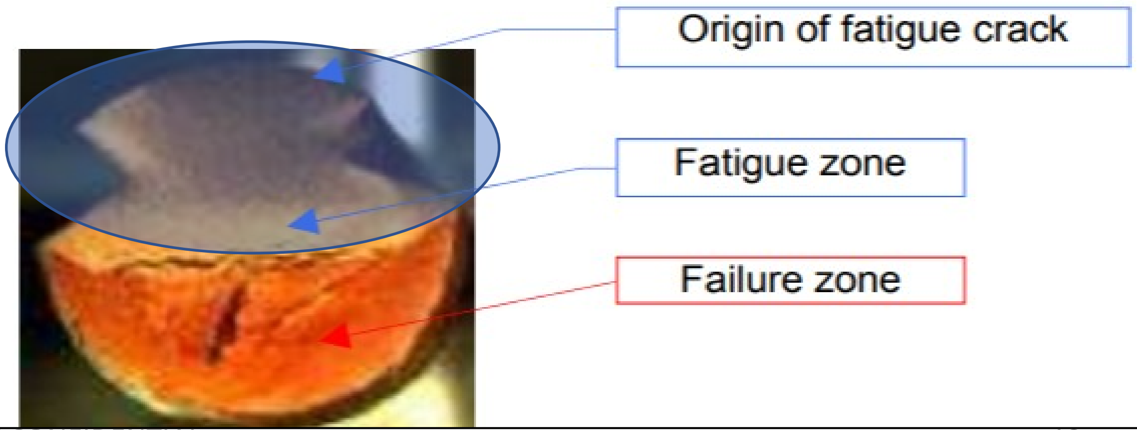


- **The main criterion used to determine the contact wire replacement of the Overhead Contact Line (OCL) is wear but, on high speed lines, the measured wear rate is very small. In this way, the contact wire lifespan of a high speed line is estimated at more than 50 years and thus it is necessary to consider the risk of having other types of system failure**
- **Because of increased wear rate of the CONTACT WIRE, The fatigue fracture is one of the most critical failures which may occur on the high speed network because it is undetectable**
- **The failure of the CW has a huge impact on traffic disruption, client discomfort (delays, speed slowdowns) and cost explosion.**

A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **The fatigue crack appearance is shown in Figure 3. The three steps of the fatigue process can be identified: crack initiation, crack propagation and failure.**
- **The origin of the fatigue crack occurred on the top of the contact wire. Indeed, a dark area corresponding to crack initiation begins on the upper edge of the wire and the crack propagates to failure by necking of the wire.**
- **One can note that these tests are reproducible and evolution of the fatigue fracture appearance remains independent of the bending strain amplitude.**





A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

The dynamic behaviour of the two flexible structures (the pantograph and the catenary) in sliding contact is very different in spite of having comparable stiffness. On one hand, the overhead line is a very long structure of wires, strongly prestressed in which bending waves propagate and, on the other hand, the pantograph is an articulated frame excited on two sides, by the train and by the overhead line, subjected to a disturbed aerodynamic environment.

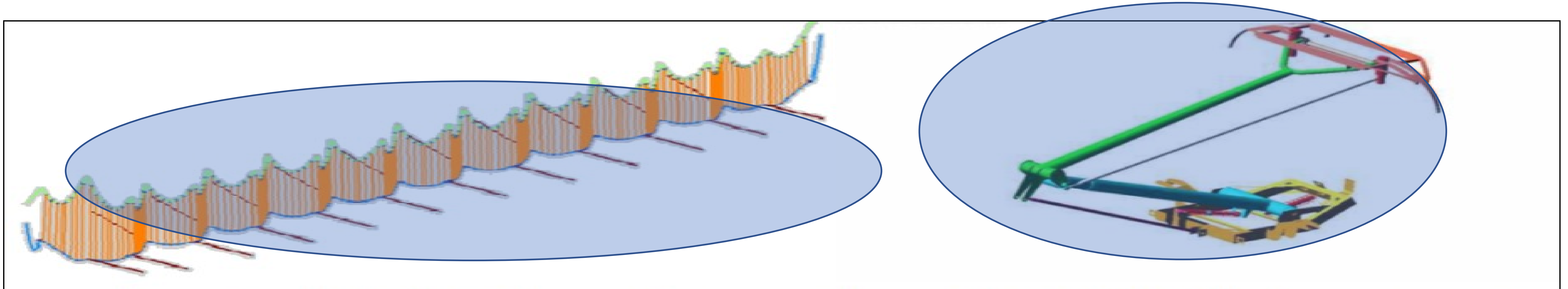


Figure 6a. (left) Finite Element Catenary; Figure 6b. (right) Multibody pantograph.

A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

The loading path is a very sensitive parameter in fatigue study. For instance, the bending waves in catenary may influence the fatigue phenomenon. Therefore, a new functionality to study stresses in the contact wire was included in OSCAR© because it provides very predictive loading path. It is necessary to study the multiaxial stresses because friction between the pantograph and the contact wire generates stresses upon plans xz and yz, the clamping force imposed by the junction claw may exceed 2kN/cm (the average stress in the contact wire is then heavily modified near this component) and last the junction claw applies a torsional stress caused by the swaying of the claw around the contact wire axis as drawn in the Figure

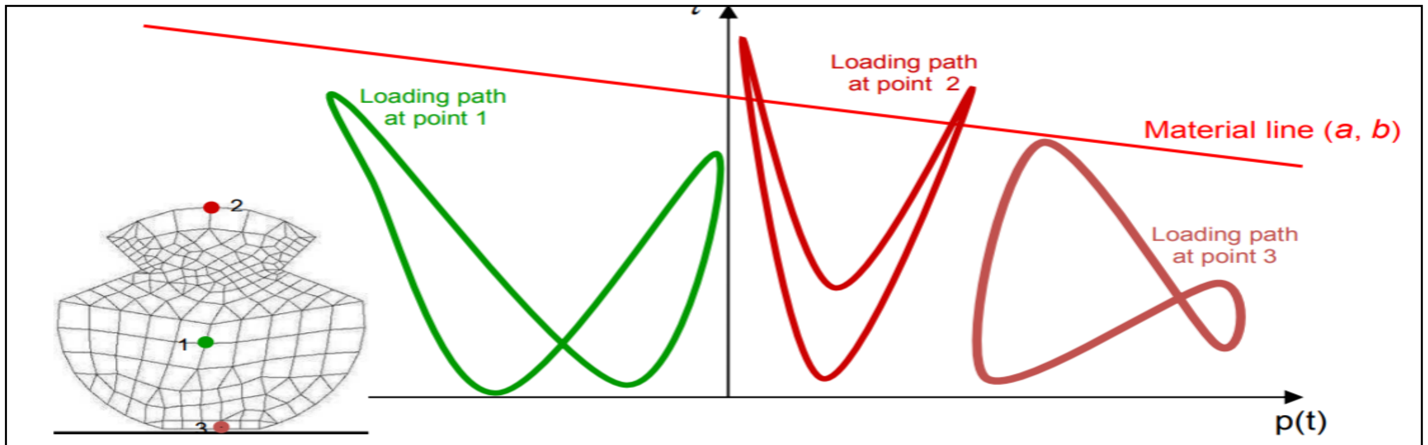
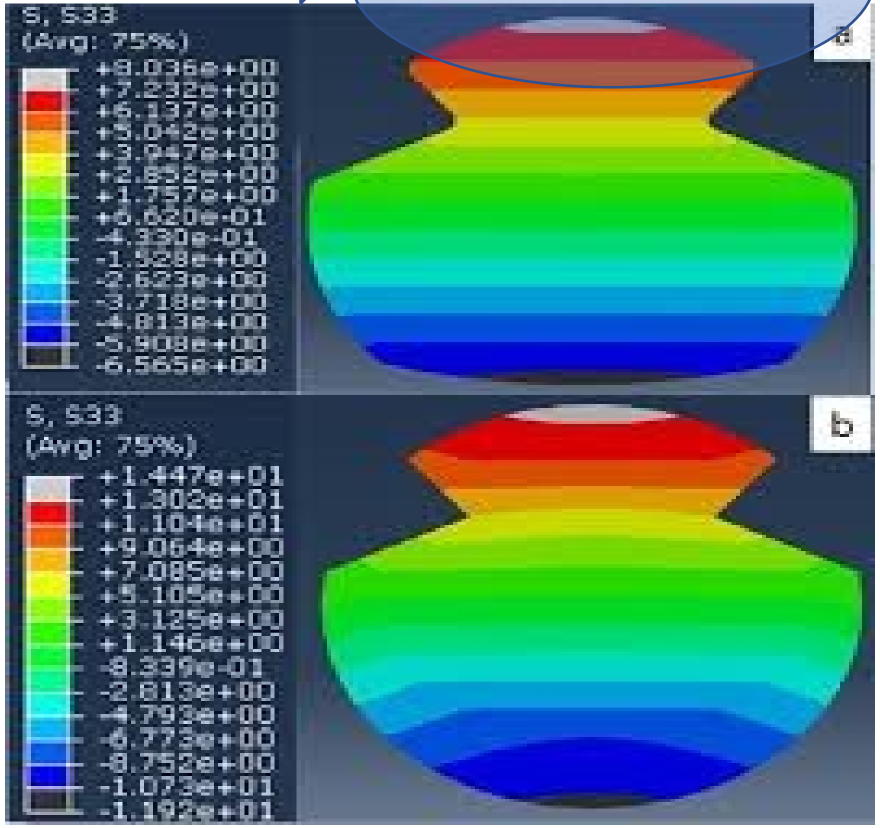


Figure 16. Dang Van Diagram theory description.

A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **The image at the bottom in Figure 17 represents values of stress obtained in the contact wire, using FE analysis. The junction claw considered as a non-deforming component. The stress tensor obtained can be used to perform a fatigue analysis by making a cumulative damage.**
- **The fatigue in the Overhead Contact Line (OCL) applied to a typical French catenary. This system failure is critical for railways operators.**
- **An analysis of the different parameters that significantly influence the fatigue phenomenon is carried out in this study. First, a preliminary analysis based on experimental results shows that involved phenomena are complex, particularly because of coupling of dynamics and wear, and because they are very sensitive to condition of use.**



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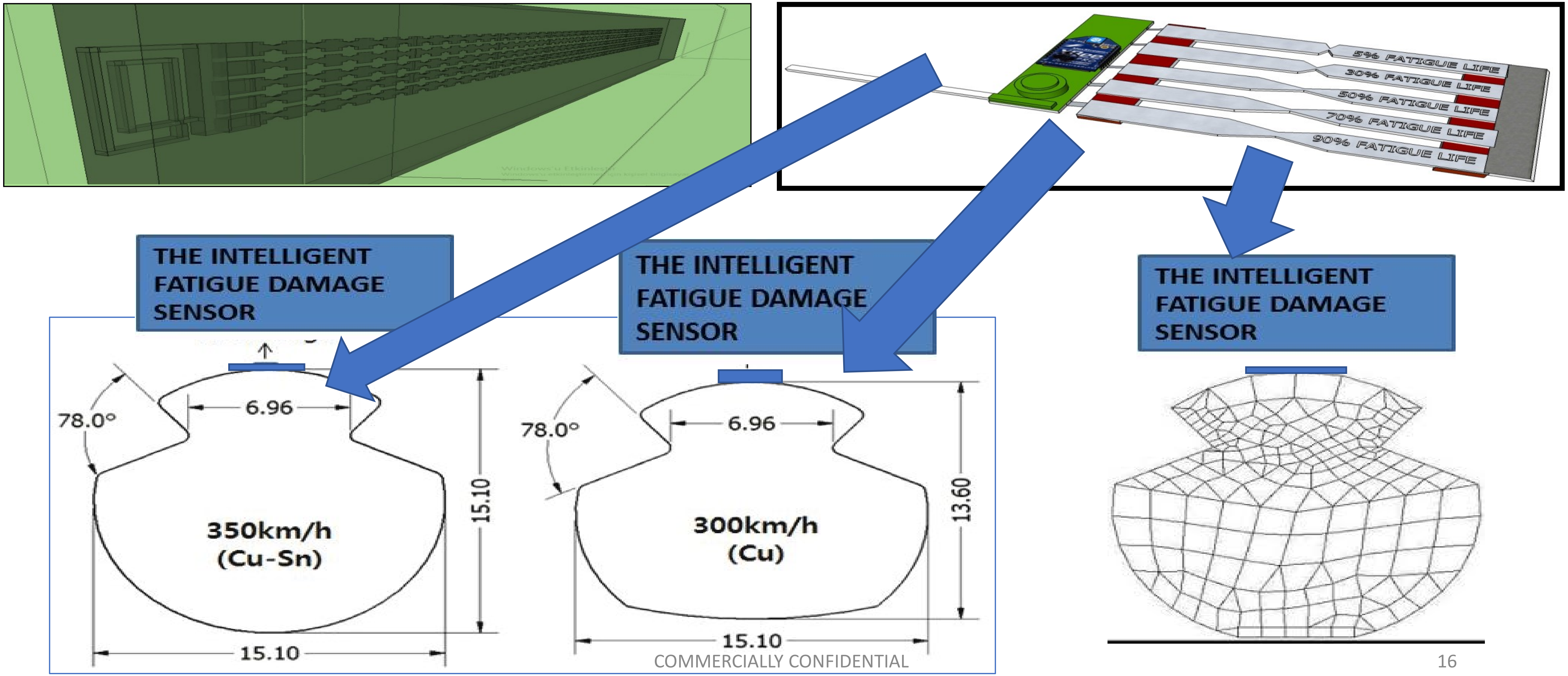

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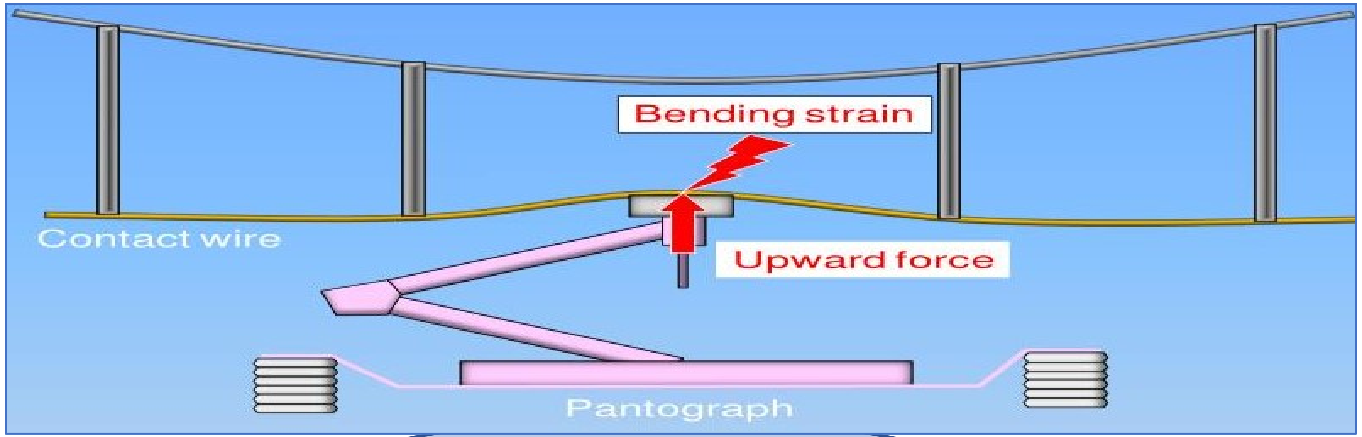

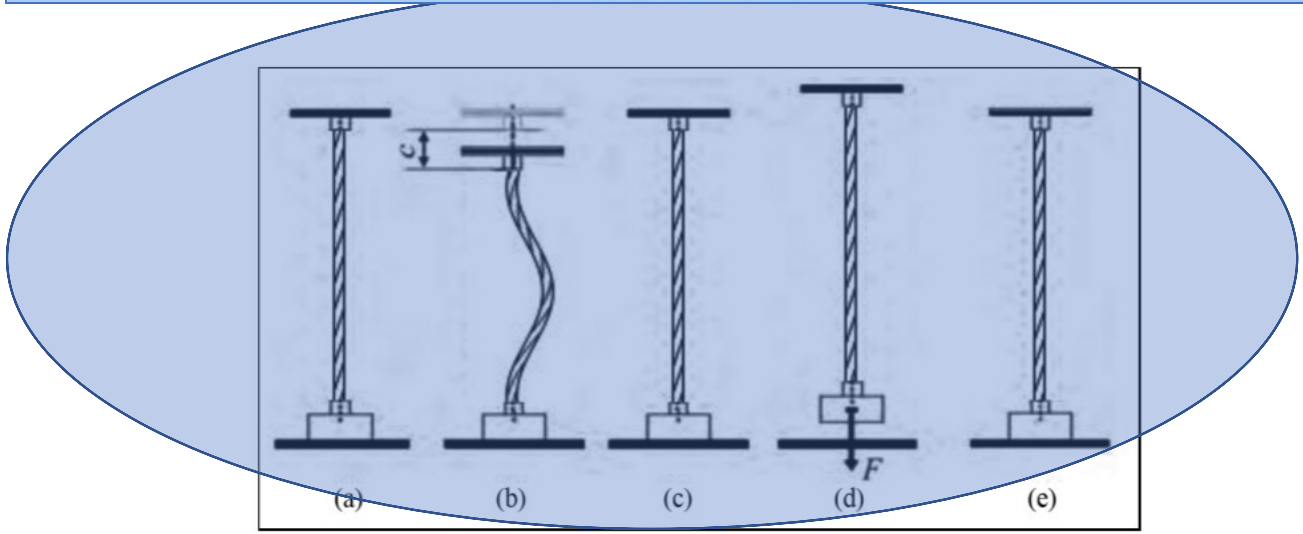

Figure 2. The dropper behavior under loading (a) A natural straightening state of dropper. (b) Some factors (such as the train passing through, or the wind and rain) lead to the compression of the dropper. (c) After the train passes through, the dropper resumes a straightening state. (d) The effect of the force interaction of the lower dropper part is expressed by F. (e) it indicates a return to (a). The diagram from (a) to (e) is a simplified equivalent vibration of the dropper under actual conditions.

- **The fatigue characteristics of power supply catenary system, many research groups have done a lot of efforts.**
- **The ANSYS finite element software and the direct integration method to simulate the pantograph-catenary coupling system dynamically.**
- **The stress history of the contact wire and followed the fatigue life of the contact wire using the linear cumulative damage theory.**
- **Calculated the fatigue life of each element of the contact wire using the rain flow counting method and the Miner linear fatigue cumulative damage theory.**

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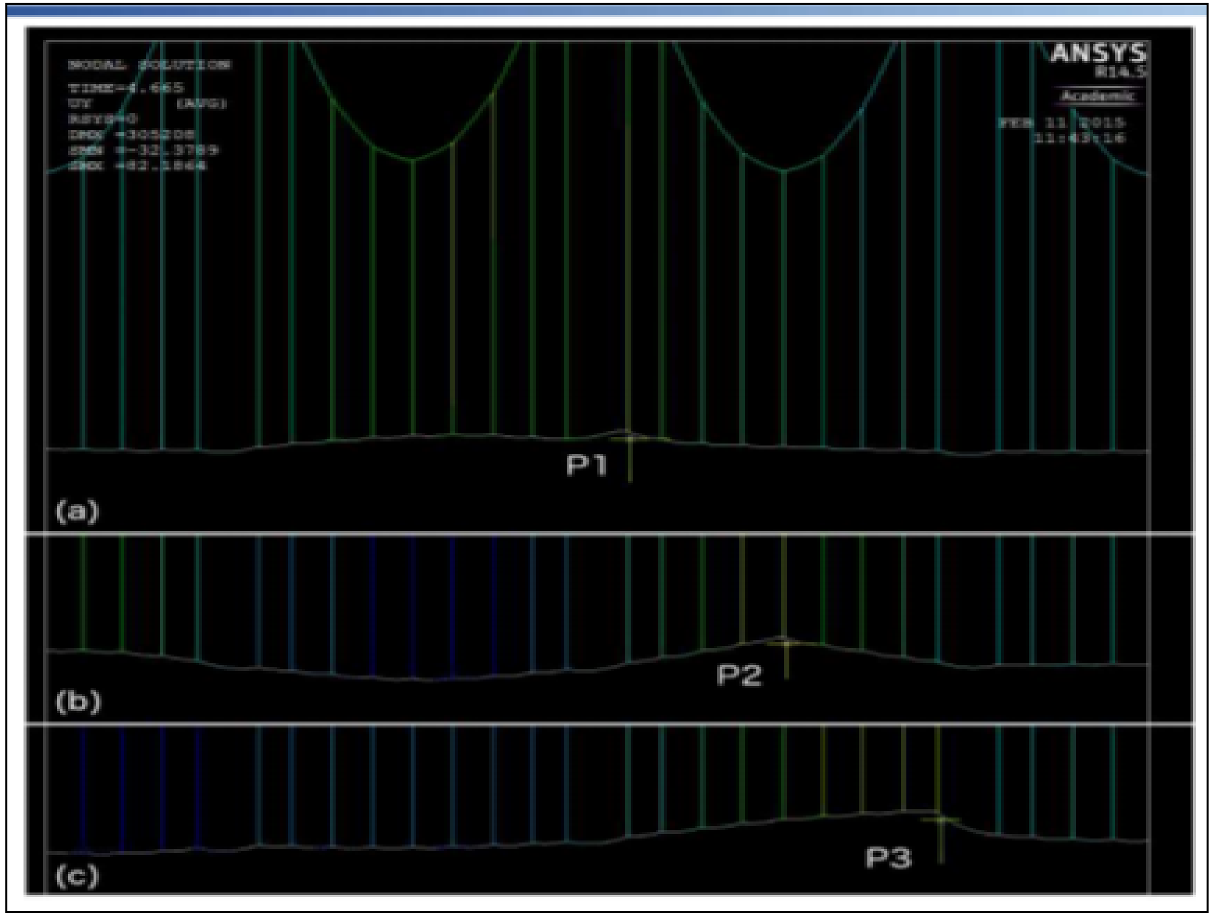
- **Reference model at 300km/h showing deformation of the contact wire local to the pantograph.**
- **Pantograph at location P1, start of span.**
- **(b) Pantograph at location P2, mid-span.**
- **(c) Pantograph at location P3, end of span.**
- **Only the contact wire and droppers are shown in (b) and (c), but are aligned with the catenary shown in (a). Same scale in each section.**



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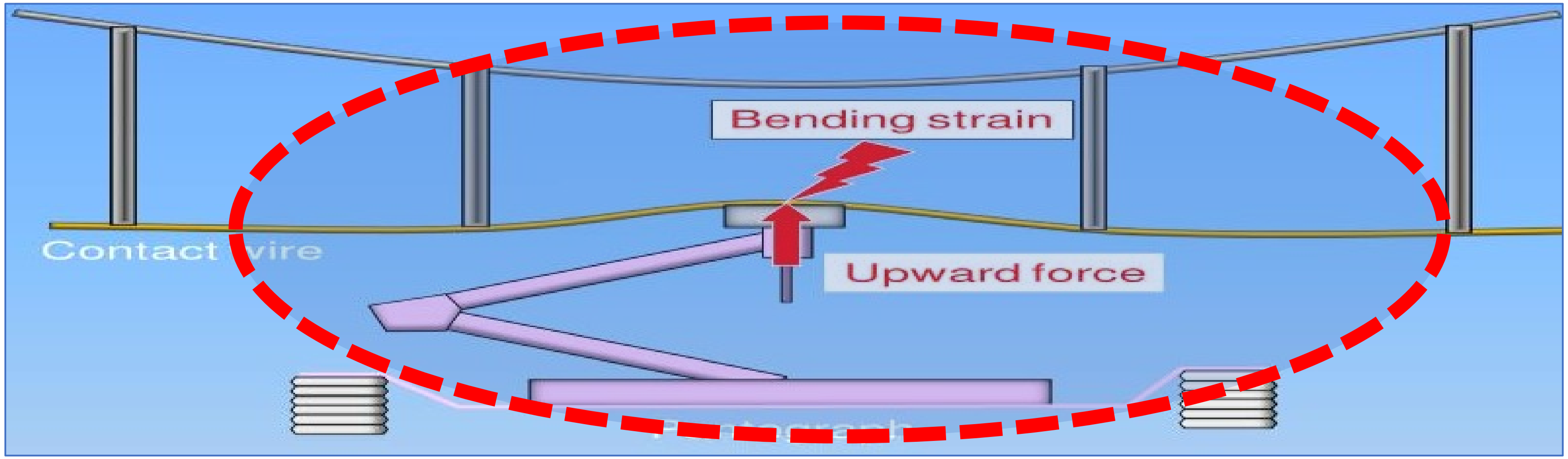

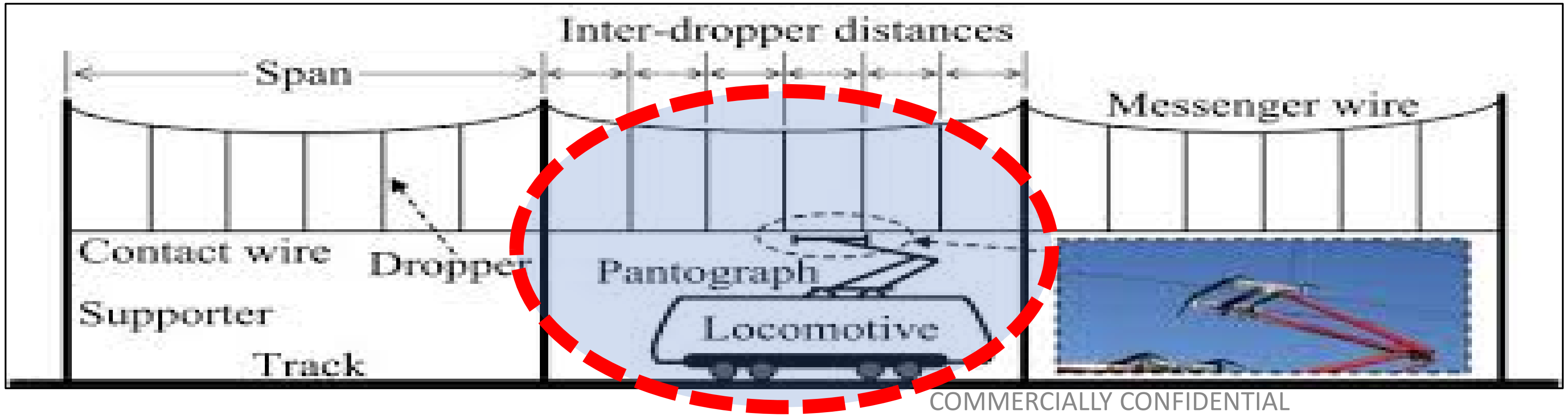

The catenary system, whose role is to supply power to electric high-speed locomotive, is erected along the railway on field and has no standby but bears long-term dynamic load such as natural wind and the pantograph–catenary contact force during the process of train running. So, fatigue is one of the main failure modes.

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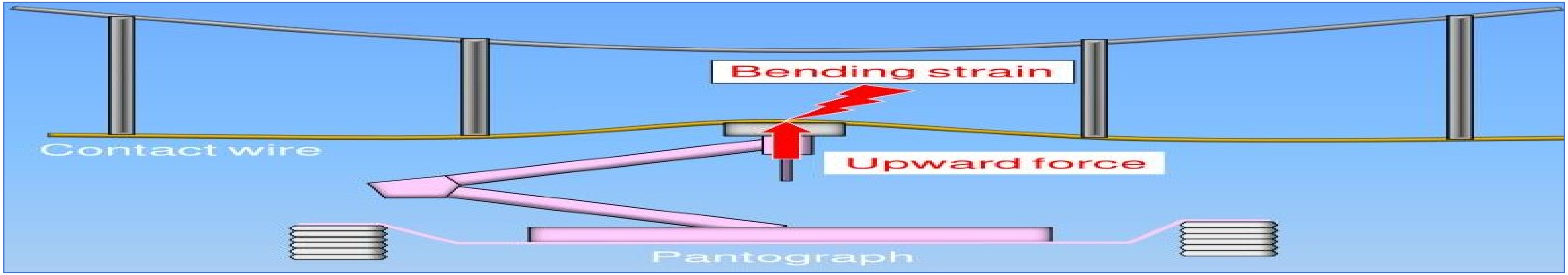
- **The main source of fatigue damage on connectors is the relative displacement between contact wires and messenger wires (Fig). Furthermore, the damage is particularly stark when resonance occurs between the connectors.**
- **Analyses of OCL vibrations on conventional lines, found that the maximum relative displacement was 40mm, whilst the frequency of precursory and residual vibrations was situated in the 0.8-8.0Hz range. These results were taken as the new criteria for fatigue evaluation.**



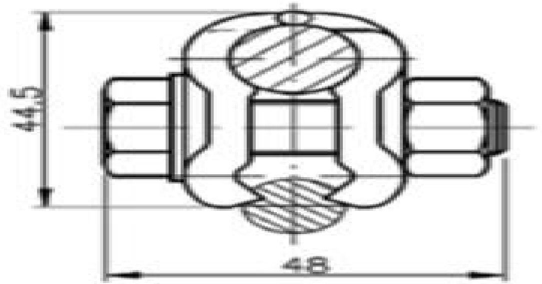
A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System
(DIMENSIONS OF CONNECTION WIRES)

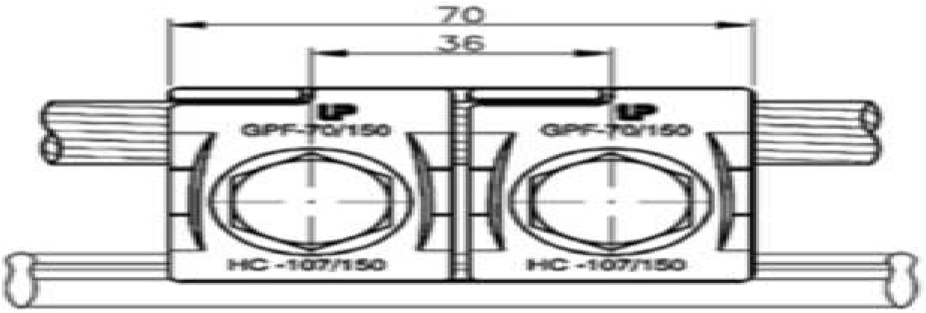
PROFILES

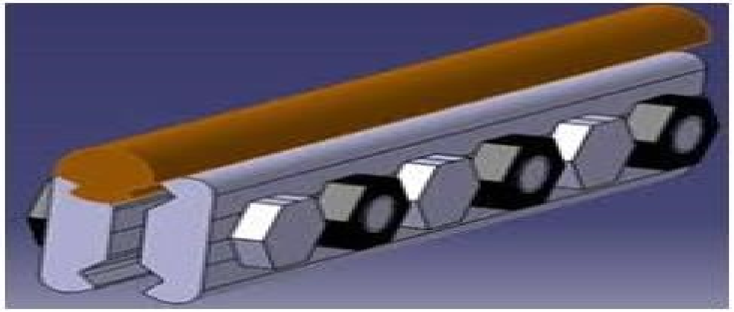
NOMINAL CROSS SECTION

Nominal cross section mm²		80	100	107	120	150
Ø (mm)	AC	10,60	12,00	12,30	13,20	14,80
	BC	-	12,00	12,24	12,85	14,50
	BF	-	11,04	11,35	12,27	13,60

E-module kN/mm²: 120 Linear expansion coefficient: 10-5/K Density 10³ Kg/m³: 8.89







No.	ID-code	Contact wire cross section	Anchoring cable cross section (mm²)	Number of bolts	Tightening Torque (Nm)	Weight (kg)	References
325 102 001	GPF 70/150	Ri 80 - 150	70 - 150	2	65	0.44	NETWORK RAIL AVE
-	GPF 70/150M	Ri 80 - 150	70 - 150	1	65	0.22	-

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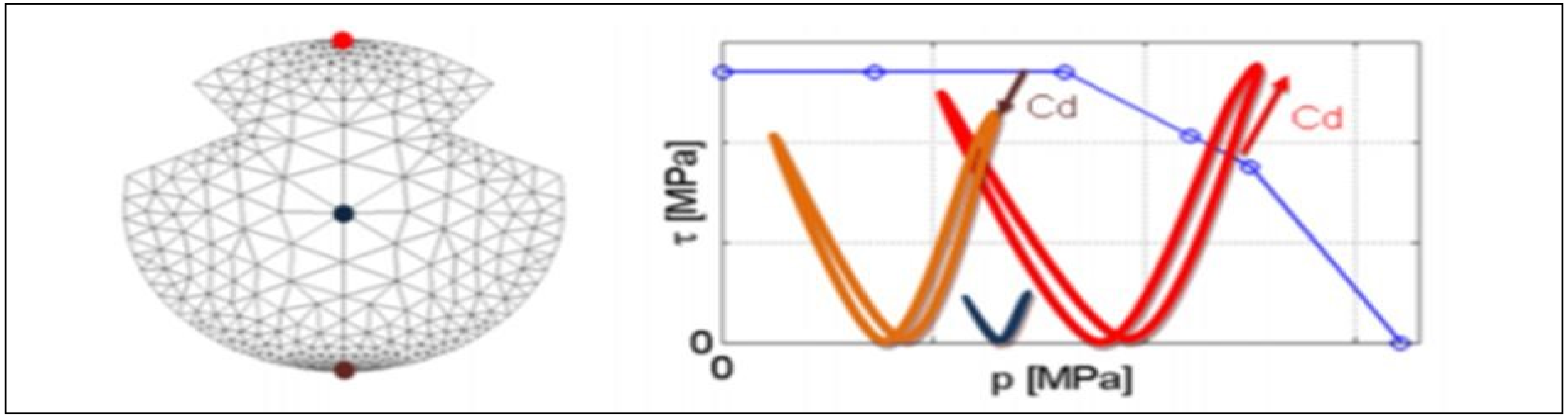
There are some research studies and medhods to find the critical fatigue locations on the connection wires.
In these studies, the full volume process has been used to compute the multi-axial stresses in the CW. With the full 3D stress field, a multi-slope Dang Van criterion can be computed at any point of the contact wire to assess the risk of crack initiation. The unlimited endurance domain has been precisely identified for the common copper alloy used for CW. The criticality of a given cycle due to a train passage is quantified by a scalar called criticality ("Cd" in the figures).



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- **The pantograph is one of the most important electric equipments in the electric multiple units (EMU), which collects the electric power from catenary for the EMU. The pantograph is mainly composed of collector head support (CHS) and carbon slipper, which is subjected to shock loads between carbon slipper and contact wire.**
- **The working conditions of pantograph are becoming worse and worse with the increasing speed of the EMU. The pantograph has been subjected to variable loadings due to the uneven track, the impact force of pantograph and catenary, and the air flow force, which may cause fatigue damage of the pantograph, shorten its service life, and affect the safety and reliability during EMU operation.**
- **When the pantograph worked for a period, some cracks were found in the pantograph CHS and the vane where fatigue failure may occur. To ensure the normal usage of pantograph and reduce accident occurrences, it is necessary to investigate the fatigue life and reliability of the pantograph CHS**

A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **The infrastructure supporting high-speed railways (as well as the high-speed train itself) is an important aspect of a high speed railway system .**
- **In particular, the contact wire that supplies electricity to the train is one of the most important components in the safe operation of a high-speed railway system. Thus, prior to updating train speeds, the reliability of contact wires should be ensured by evaluating their mechanical characteristics and durability.**
- **Wear failure (caused by friction between the pantograph and contact wire) has been investigated because fatigue life is considered to be much longer than wear life. Therefore, previous studies focused only on wear failure.**
- **However, since the reports of several fatigue failures from Shinkansen in Japan, the study of fatigue damage and contact wire failure has become necessary**

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- **The most important factor influencing the fatigue life of the contact wire is the uplift amount due to the uplift force from the impact of the pantograph. The uplift amount is the vertical displacement of the contact wire caused by the pushing force generated as the pantogragh passes.**
- **The uplift amount is directly related to the bending strain of the contact wire and is the most important factor in determining the fatigue life of the contact wire.**
- **The uplift amount increases as the train speed increases, indicating that higher train speeds induce greater mechanical fatigue on contact wires.**
- **The fatigue life of contact wires should be evaluated accurately according to the uplift amount in order to estimate the replacement period necessitated by increased train speeds.**

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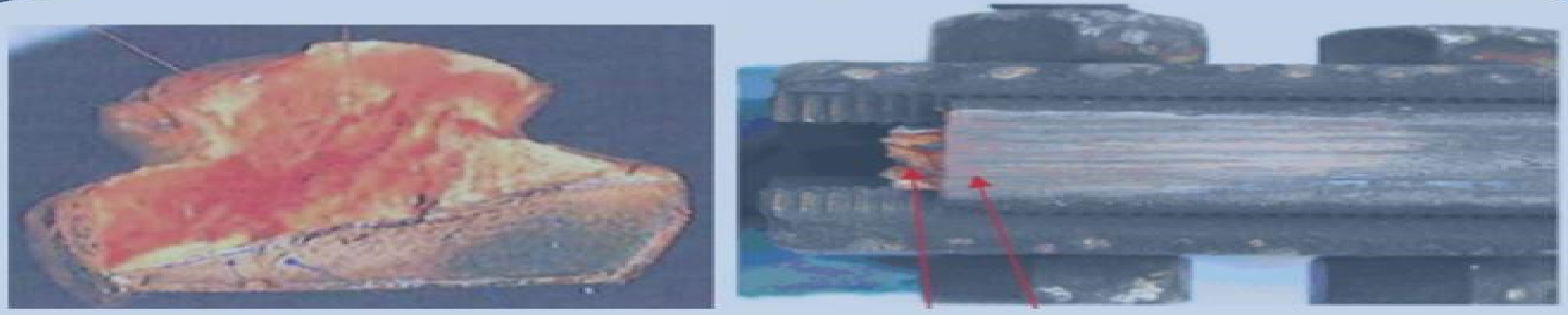
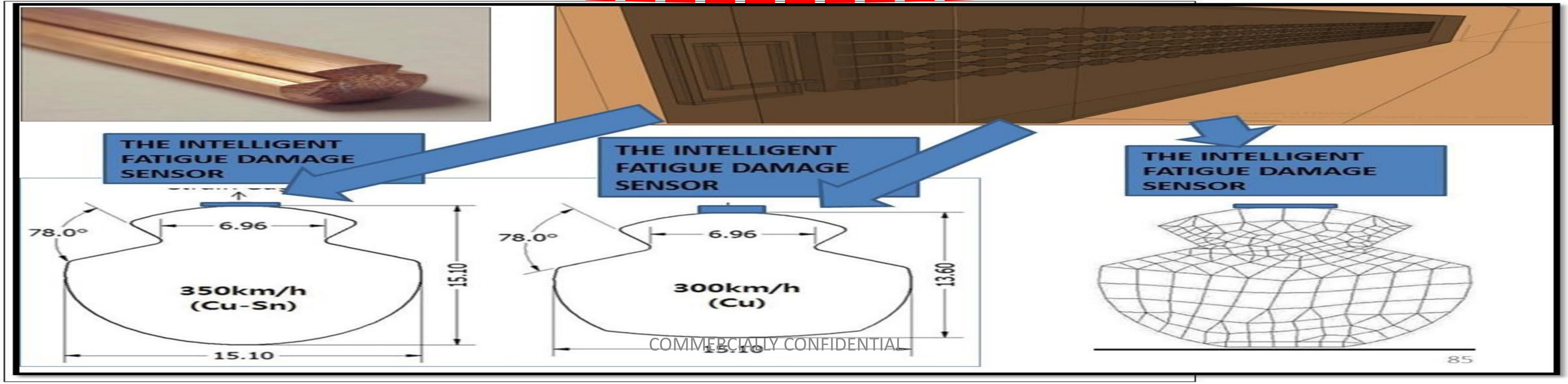
- **The fatigue fracture is one of the most critical failures which may occur on the high speed network because it is undetectable and it has a huge impact on traffic disruption. The contact wire lifespan of a high speed line is estimated at more than 50 years and thus it is necessary to consider the risk of fatigue.**
- **The Railway Technical Research Institute in Japan studied this phenomenon for a long time and performed experimental tests.**
- **Using these results and by comparing with failures occurred in France, a preliminary analysis is carried out to identify parameters which significantly influence the fatigue phenomenon.**



A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **Nowadays, the main criterion used to determine the contact wire replacement of the Overhead Contact Line (OCL) is wear but, on high speed lines, the measured wear rate is very small. In this way, the contact wire lifespan of a high speed line is estimated at more than 50 years and thus it is necessary to consider the risk of having other types of system failure.**
- **The fatigue fracture is one of the most critical failures which may occur on the high speed network because it is undetectable and it has a huge impact on traffic disruption, client discomfort (delays, speed slowdowns) and cost explosion.**



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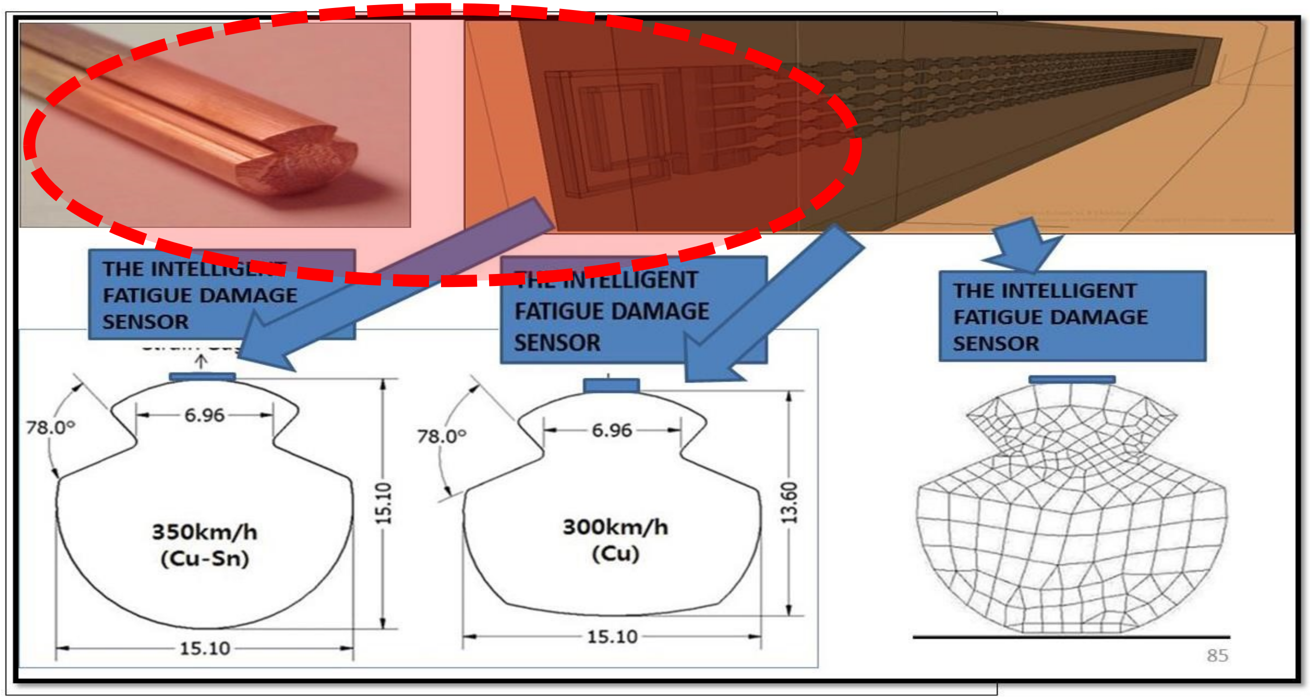
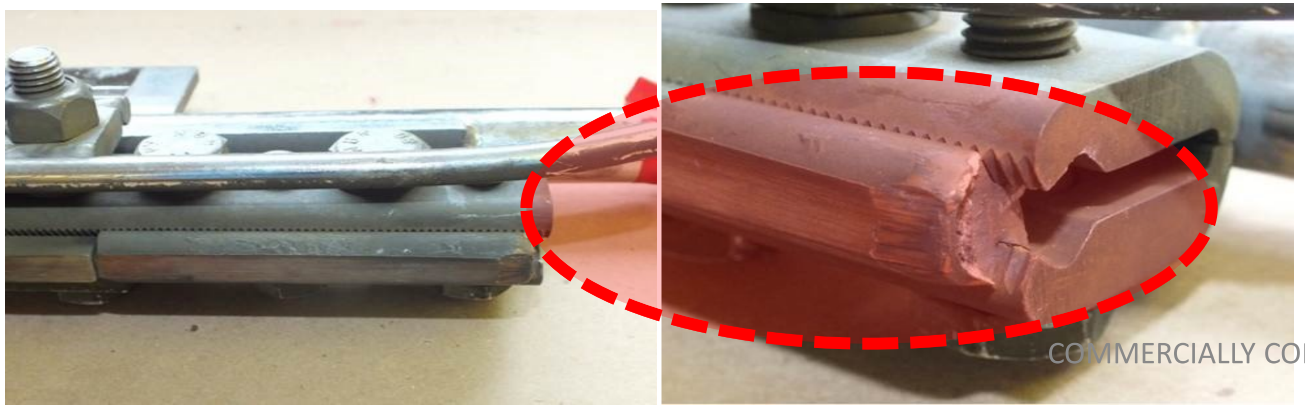
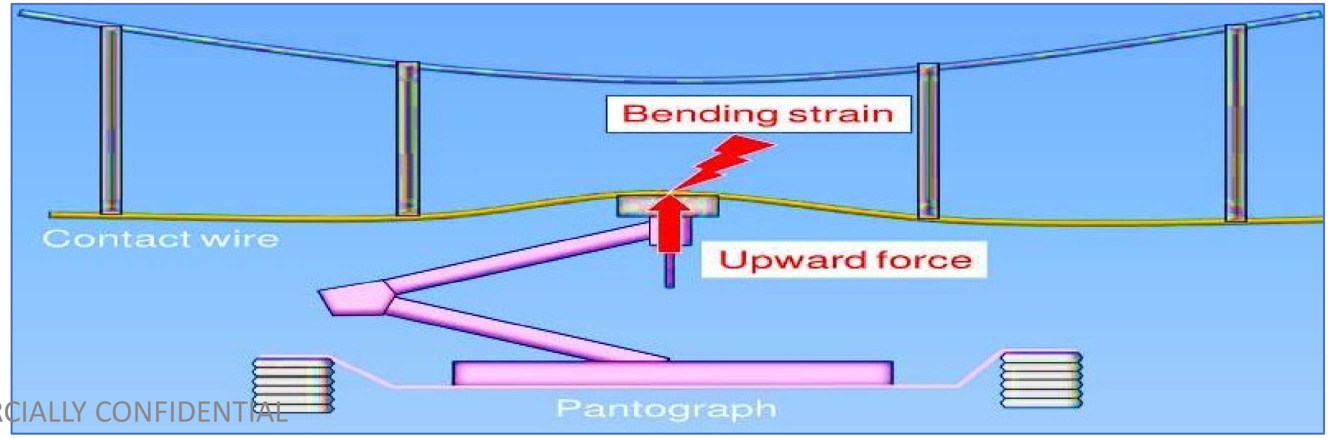




- **Some fatigue failures have already occurred on the overhead contact line between Paris and Lyon. This overhead line was replaced after only 29 years of use because fatigue failures took place under the junction claws. This component, commonly used in maintenance on classical lines, appeared to be inadequate when used on high speed lines.**
- **Its heavy weight and its high stiffness produce important dynamic loads and arcing with the pantograph passage.**
- **A modification of the maintenance procedure limits the number of settled claws and their duration, but the fatigue could take place on other lines.**

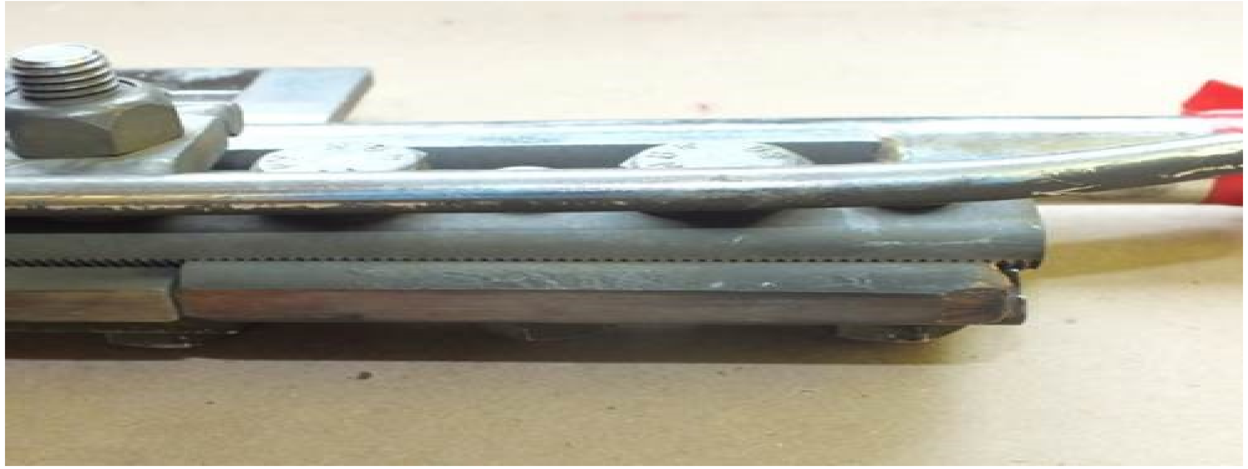
A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **The dynamic behaviour of the two flexible structures (the pantograph and the catenary) in sliding contact is very different in spite of having comparable stiffness.**
- **On one hand, the overhead line is a very long structure of wires, strongly prestressed in which bending waves propagate and, on the other hand, the pantograph is an articulated frame excited on two sides, by the train and by the overhead line, subjected to a disturbed aerodynamic environment**



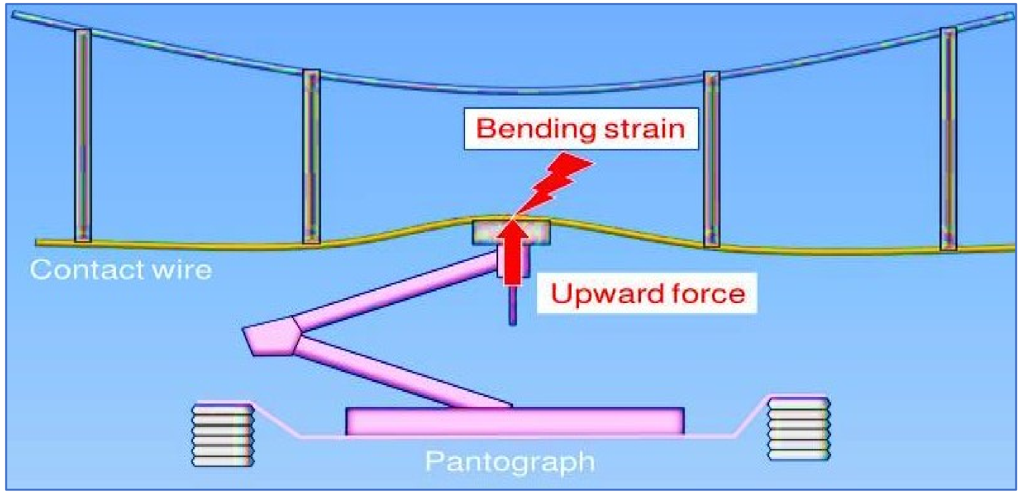
A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

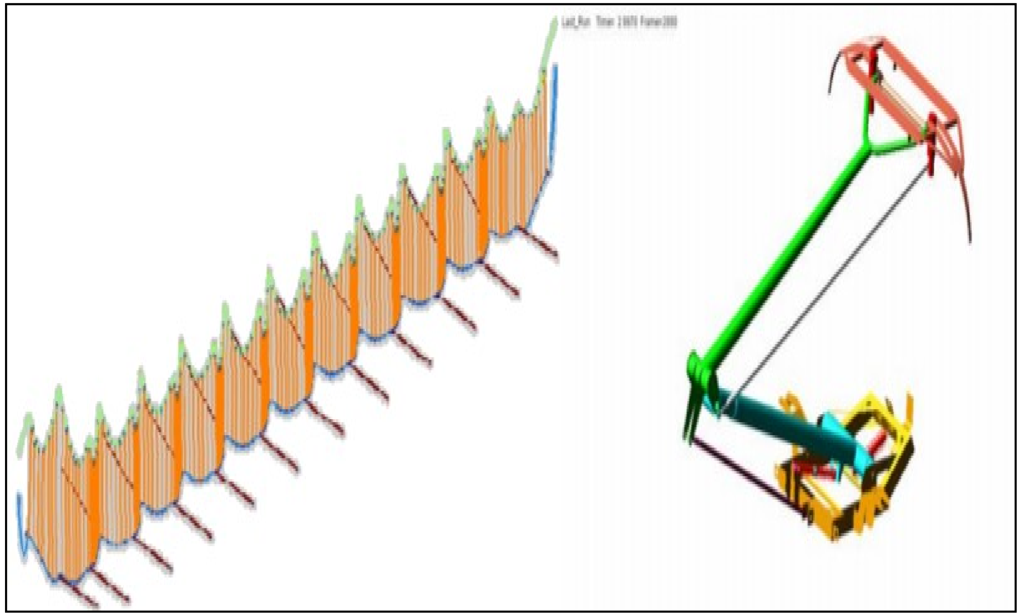
- **The component is used to connect two contact wires because of a breakage or to reinforce a weak point of the wire. Its mass is greater than the apparent mass of the catenary. When the pantograph passes under this component, it sets off a significant dynamic loading associated to high level of stress.**
- **Figure illustrates the contact wire fatigue fracture appearance obtained inline under a junction claw and Figure shows that the contact wire rupture occurred at the boundary of the junction claw.**



A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

- **As railways are increasingly electrified service levels depend on an increase in life and reliability of overhead electric power supplies beyond the performance of current materials and technology. Overhead power lines are highly stressed structures without redundancy. Their failure in service is caused by a combination of wear, fatigue cracking, and corrosion.**
- **Their life/failure is controlled by material behaviour under combined cable tension, dynamic load from current collection pantographs, and environmental loading.**
- **Dynamic modelling of the overhead line catenary system (e.g. finite element).**
- **Fatigue failure of overhead line systems, and the application of new materials/ configurations able to dramatically increase life.**





A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

FOR EXAMPLE:

- **The total mileage of China's high-speed rail is bigger than 22,000 km, exceeding the sum of all other countries in the world by the end of 2016. The pantograph catenary system is an important component of the traction power supply system of the high-speed train, as shown in Figure.**
- **Dropper is the support of the whole pantograph-catenary system, and it is the transmitter of vibration and force between messenger wire and contact wire, and the key component of the safety operation of power supply catenary. During exploitation of high-speed railway, the cyclic stress appeared in a dropper may cause the fatigue failure of dropper.**
- **It directly leads to failure of train running. At high speed and large traffic density, the failure will cause more frequent interference to the running state of the catenary system.**
- **Worth to notice that the cyclic dynamic stress amplitude of dropper is very high, and fatigue damages can be easy to be occurred. Therefore, the study of fatigue life of catenary parts such as dropper is important for ensuring the high reliability of pantograph-catenary system and the safe operation of high-speed train.**

A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor and SENSOR NETWORK for Structural Fatigue Damage Monitoring of CATENARY WIRES OF High Speed Trains and Smart Predictive Maintenance System

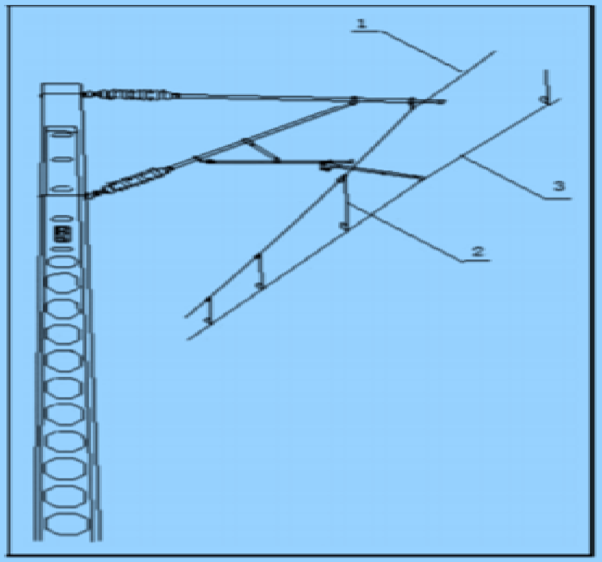
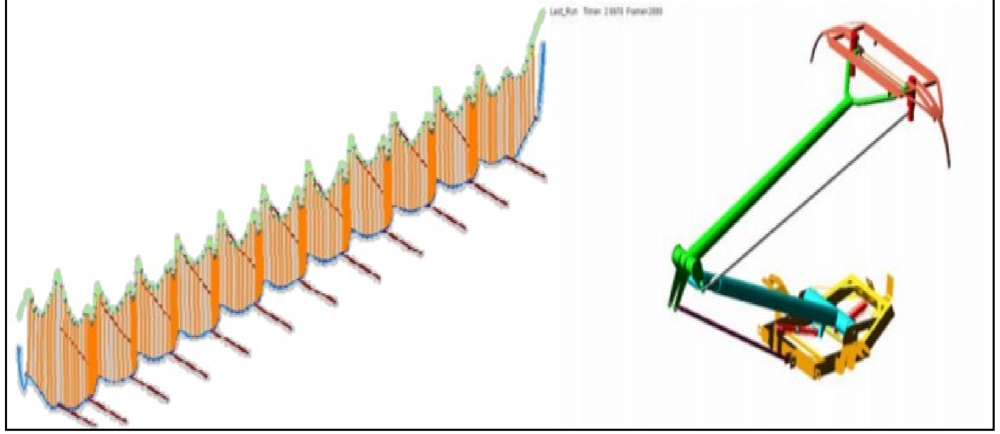


Figure 1. The pantograph-catenary system.
1—messenger wire, 2—dropper, and 3—contact wire.



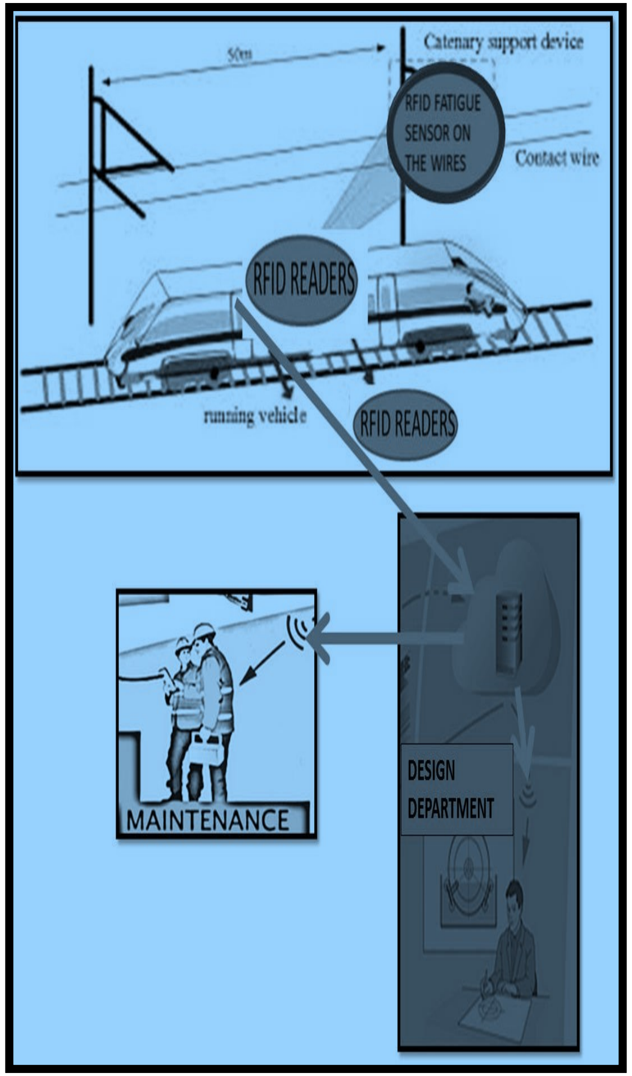
- Dropper is an important component of pantograph-catenary system employed in high-speed railway.
- The cyclic stress in dropper can lead to the fatigue failure during operation.
- The study of the fatigue life of dropper is the premise to ensure the safe exploitation of the train.
- The pantograph catenary system is an important component of the traction power supply system of the high-speed train, as shown in Figure.
- Dropper is the support of the whole pantograph-catenary system, and it is the transmitter of vibration and force between messenger wire and contact wire, and the key component of the safety operation of power supply catenary.
- During exploitation of high-speed railway, the cyclic stress appeared in a dropper may cause the fatigue failure of dropper.

A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks (INTELLIGENT RAILWAY APPLICATIONS)

INTELLIGENT Condition monitoring systems for railways

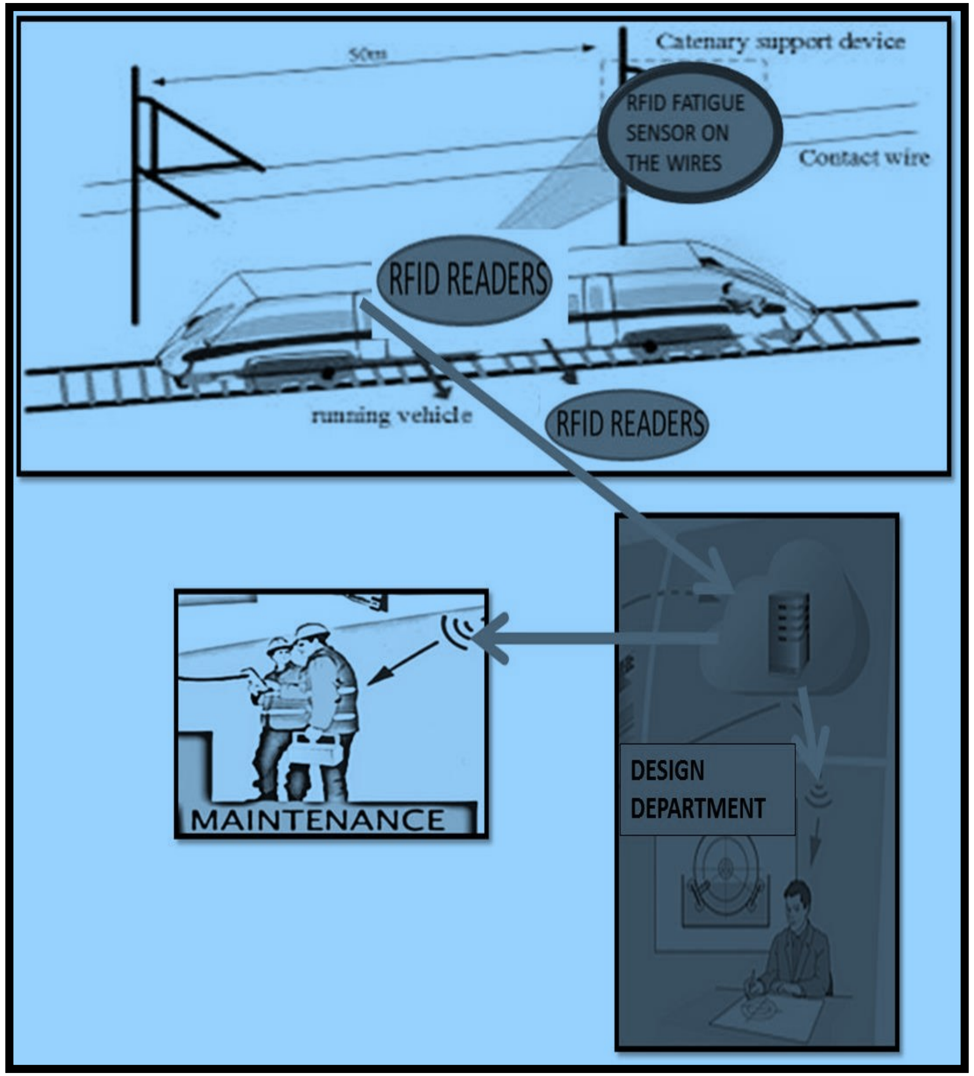
Our Solution's focus on productivity improvement, products include:

- **A predictive system for condition-based maintenance planning based on the early-detection and warning of potential equipment failures depending on FATIGUE AND OTHERS**
- **Effective implementation and management of PARTS and THE SYSTEM condition monitoring.**
- **A fully configurable management system that acquires, manages and classifies data alerts from subsystems across multiple fleets**
- **Business-driven data management solutions. In-depth knowledge of business and industry is required to understand the management of data and information with regards to a company's core business purpose.**
- **These Solutions has the capacity to offer total control of business, based on complex assets and combining in-house expertise in the railway industry with big data techniques and business intelligence.**



A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor (RAILWAY APPLICATIONS)

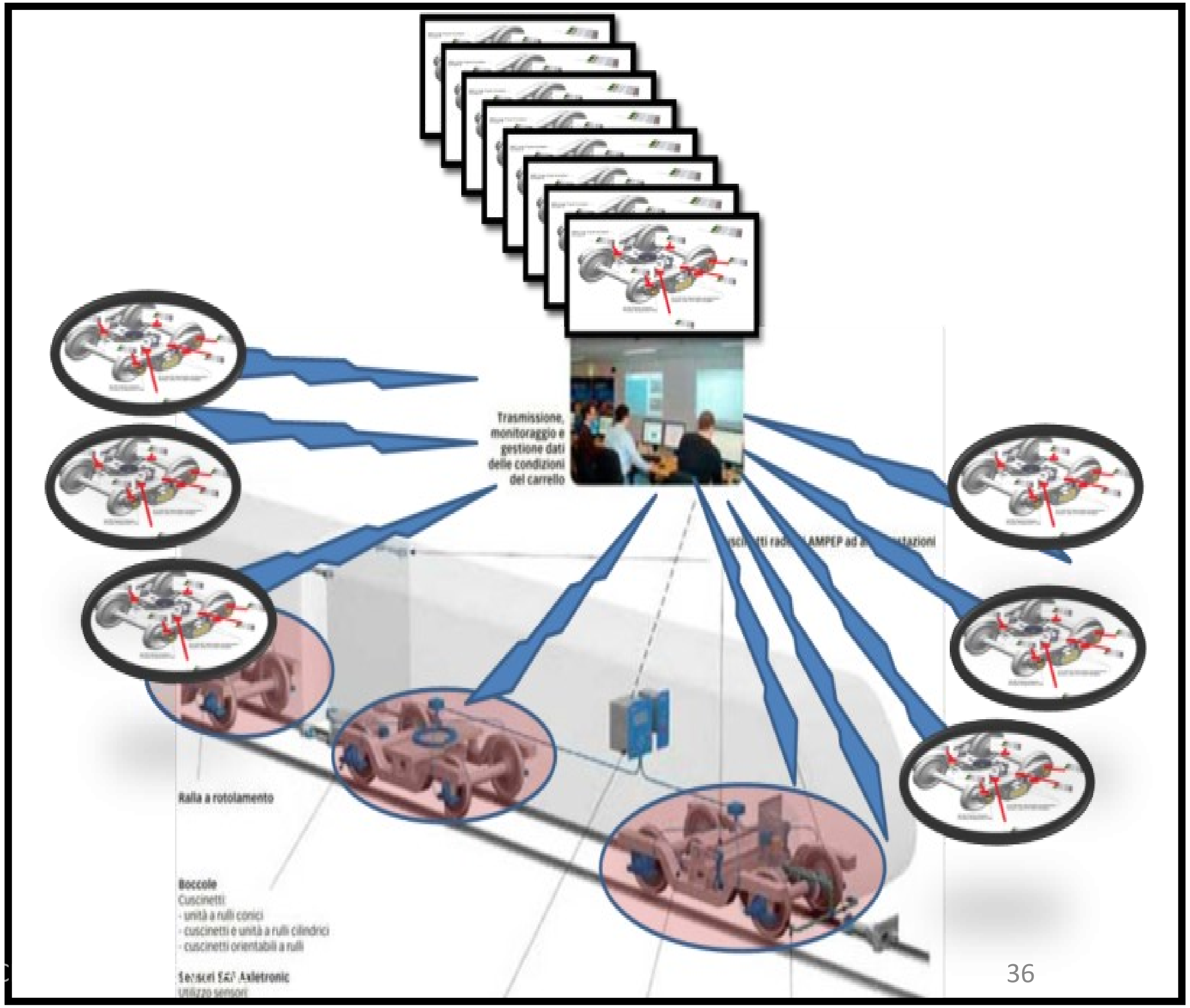
- **Fatigue characteristic is important not only to railway systems but also to many other machines and large structures.**
- **The fatigue strength reliability, one of the important study themes is the strength or fatigue characteristic of each railway system component that is subject to repeated loads during use.**
- **The reason why it is necessary to consider the fatigue characteristic carefully is that fatigue is a microscopic fracture caused by the initiation and propagation of a crack due to a cyclic slip deformation of the size of a single grain, that fatigue occurs even under a stress smaller than the strength characteristic under a static load (e.g., tensile strength), and that it can suddenly lead to a fatal fracture without causing any macroscopic plastic deformation.**



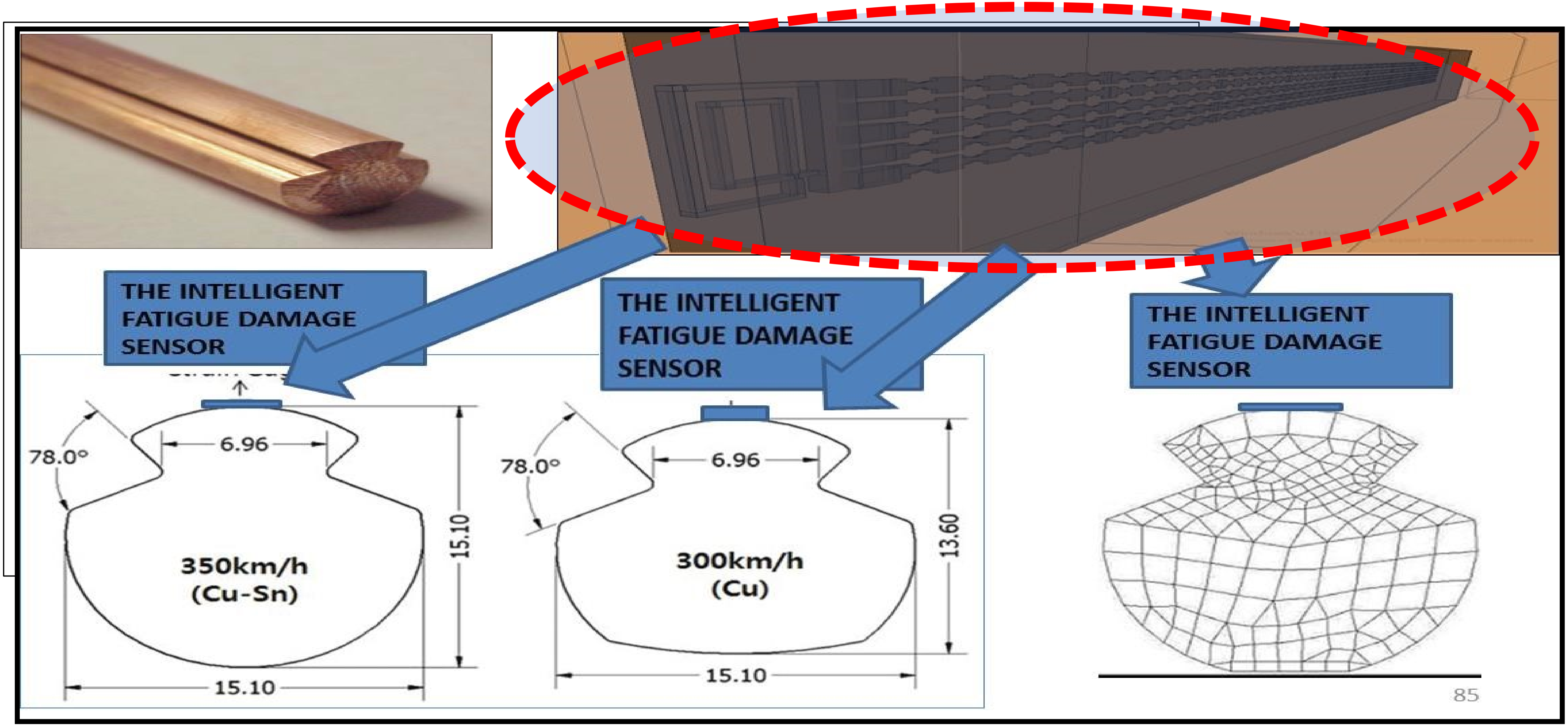
A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks (RAILWAY APPLICATIONS)

HARWARE AND SOFTWARE Products related to INTELLIGENT Solution's business management capabilities include:

- **A flexible computerized maintenance management system specifically designed for the railway industry, where the key information is properly handled to generate valuable knowledge and to make decisions aimed at optimizing your business**
- **One single place for interacting with all the key information from resource planning software, and any other data source needed for business-driven data management**

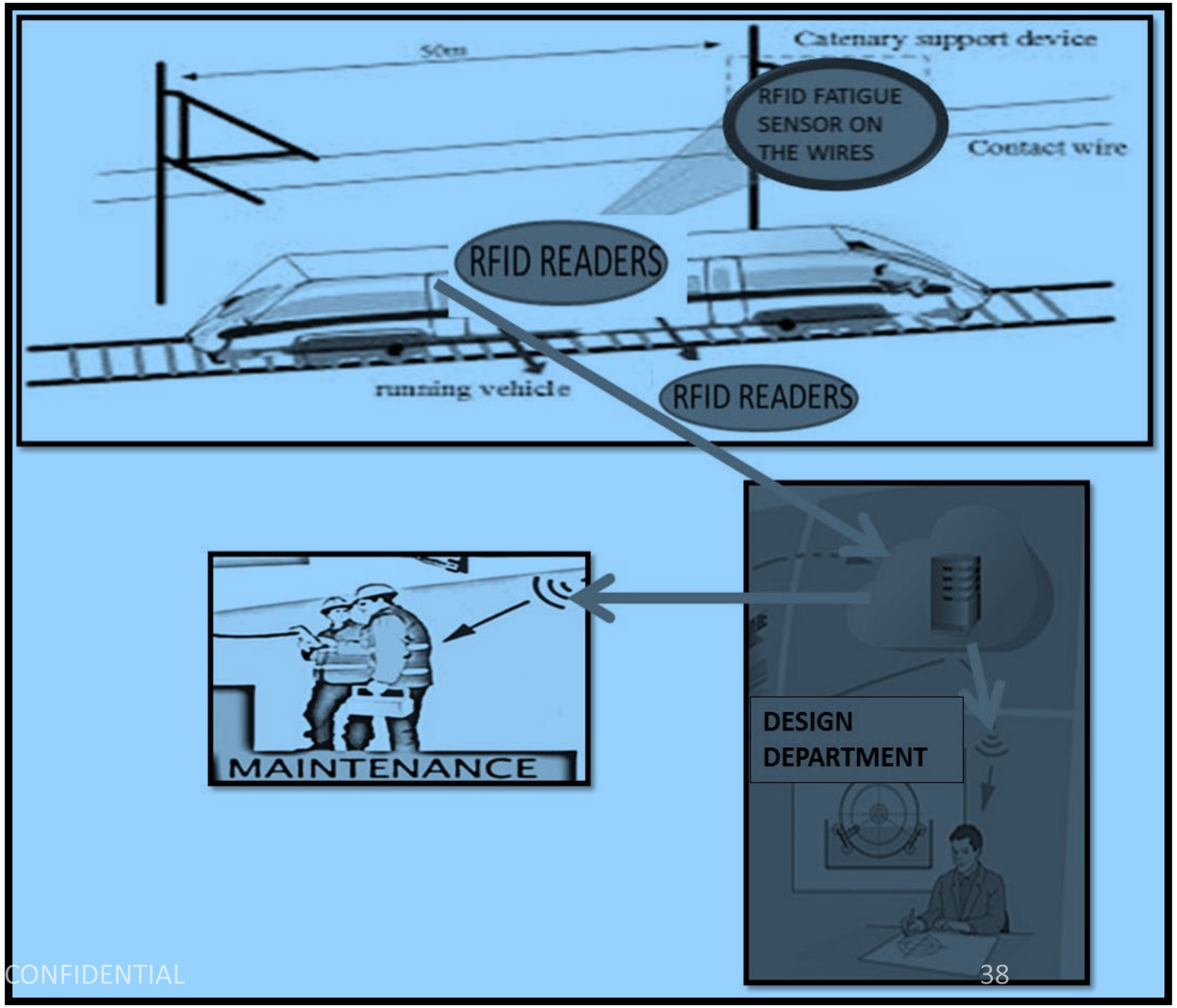


A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor (RAILWAY APPLICATIONS)

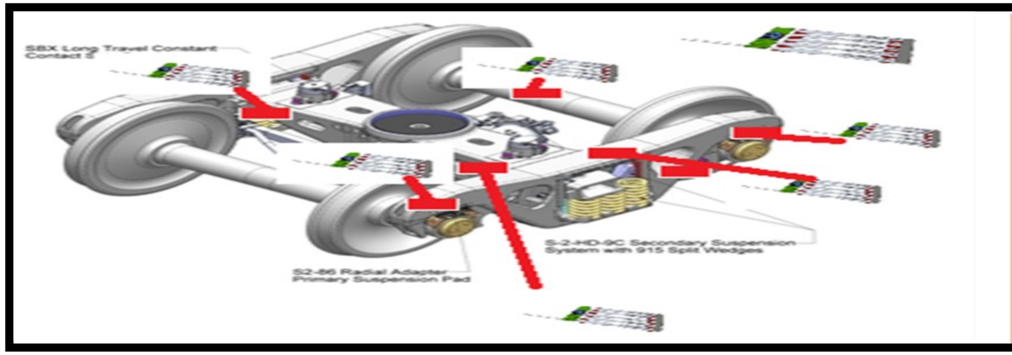


A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks (RAILWAY APPLICATIONS)

- **WITH THE FATIGUE INTELLIGENT SENSOR SYSTEM, the availability of 'big sensor data' techniques provides smart solutions with the ability to extend wheel lifecycles in accordance with customer needs.**
- **This leads to more efficient and effective maintenance, as well as increased fleet availability for service operations.**
- **The sensor network system manages and integrates the information coming from the fatigue damage monitoring systems,**
- **WITH THE FATIGUE INTELLIGENT SENSOR SYSTEM, critical damage warning systems for consistency in operations and maintenance**



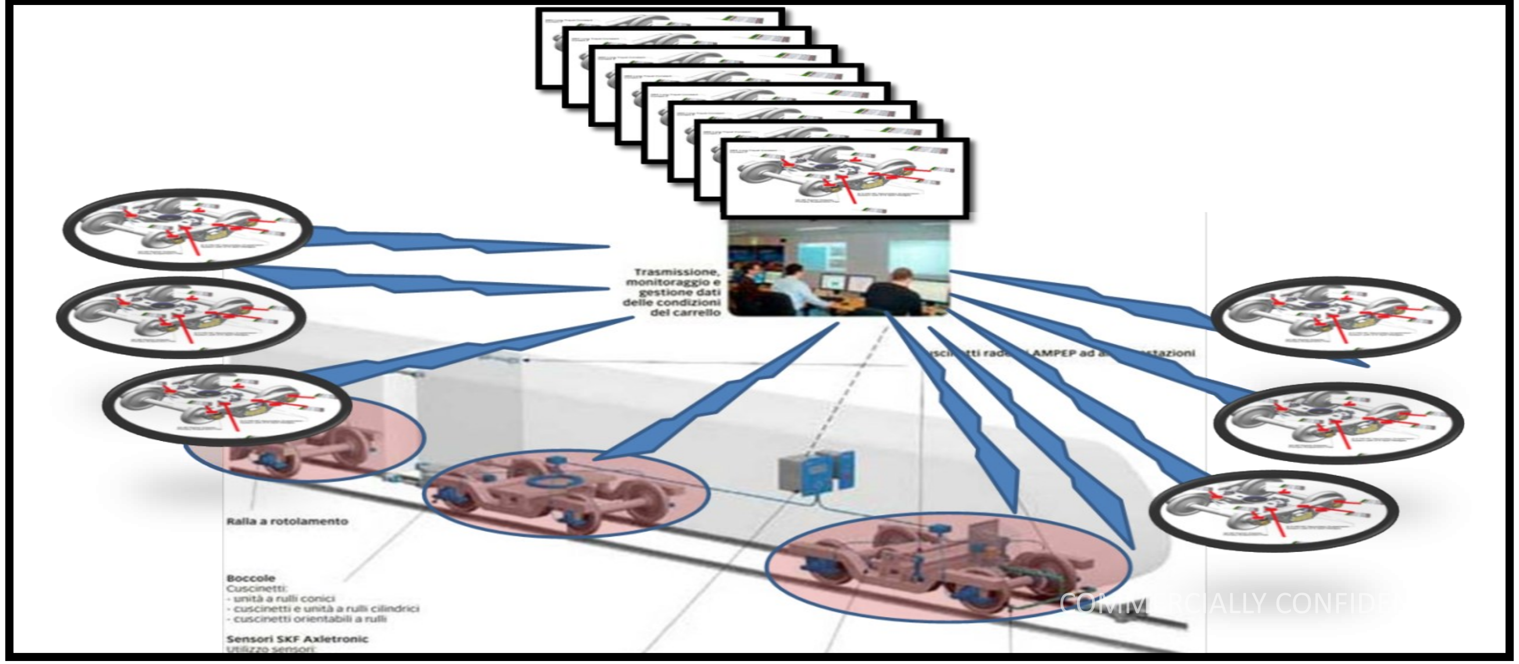
A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks
(RAILWAY APPLICATIONS)



The Fatigue Critical HOT SPOTS in BOGIES and the applications of Smart fatigue damage sensors in order to monitor the RESIDUAL FATIGUE STRENGTH or Fatigue Lifetime.

IN RAILWAY STRUCTURES, Specific and Fatigue sensitive regions, locations under high loads, predetermined and formerly known-experienced spots.

Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor Network and Fatigue Health Monitoring Center for BOGIES



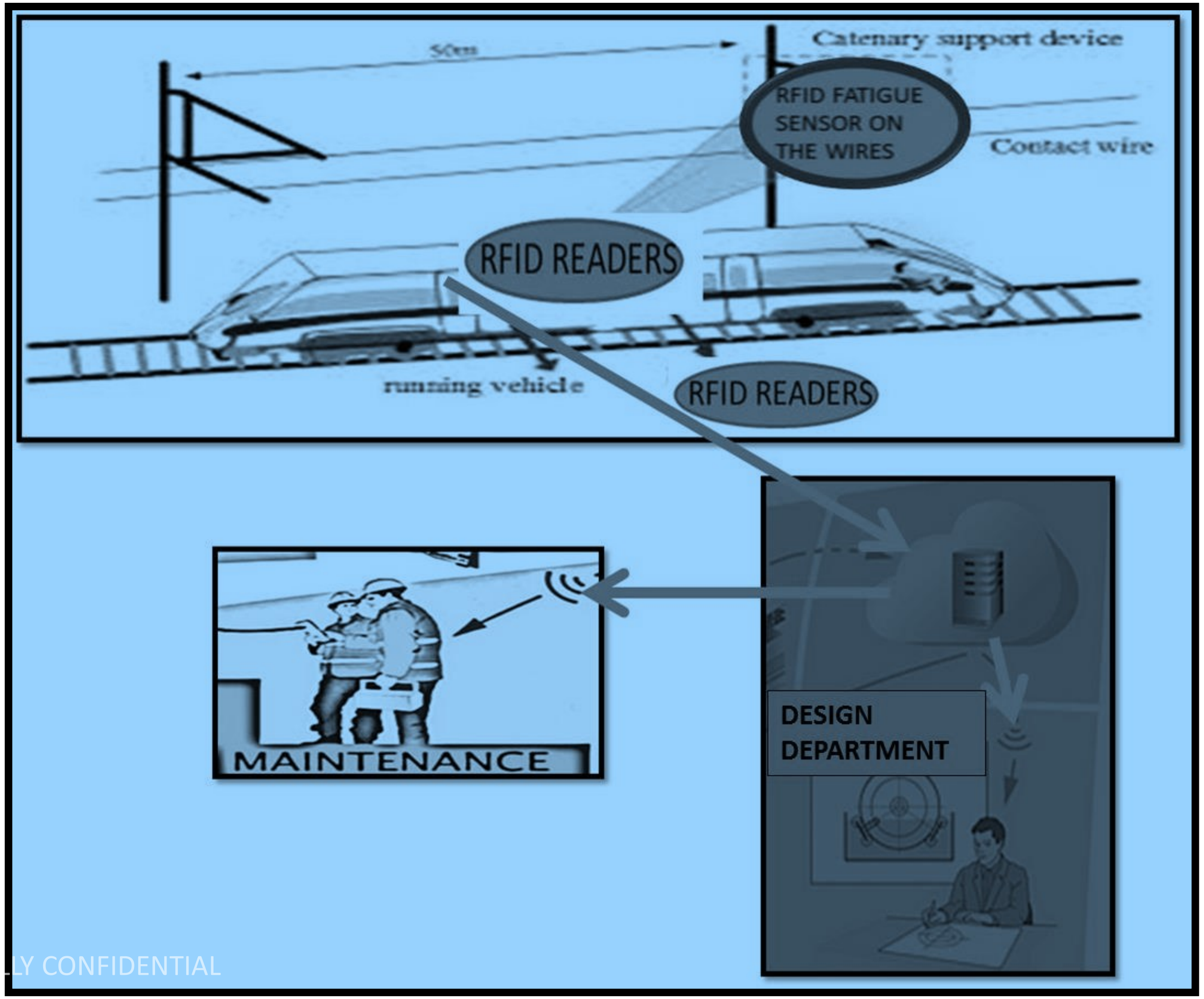
- **DO MAINTENANCE BASED ON THE STATE OF THE STRUCTURE AS NEED ARISES**
- **INCREASES AVAILABILITY**
- **REDUCES MAINTENANCE COSTS**
- **INCREASES RELIABILITY**

THE LIST OF RFID CHIPS STORED STRUCTURAL FATIGUE MANAGEMENT INFORMATION OF EACH FATIGUE CRITICAL PART OF RAIL STRUCTURES

- **A) THE OPERATIONAL HISTORY OF EACH CRITICAL COMPONENT**
- **B) THE MAINTENANCE OR FATIGUE MAINTENANCE HISTORY OF EACH COMPONENT**
- **C) THE INFORMATION RELATED TO THE CONFIGURATION OF THE RAIL PART IN WHICH THE COMPONENT IS INSTALLED**
- **D) THE DATE THE COMPONENT MANUFACTURED**
- **E) THE NAME OF THE SUPPLIER OF THE COMPONENT**
- **F) THE SERIAL NUMBER OF THE COMPONENT**
- **G) THE PART NUMBER OF THE COMPONENT.**
- **G) THE PART EXPECTED SCHEDULED REPAIR TIME**
- **H) THE PART MATERIAL PROPERTIES**
- **I) THE PART REDESIGNS NEEDS AND DESIGN MODIFICATION OR REVISION**
- **K) THE PART CONNECTION PROPERTIES (RIVET, WELDED ETC...)**

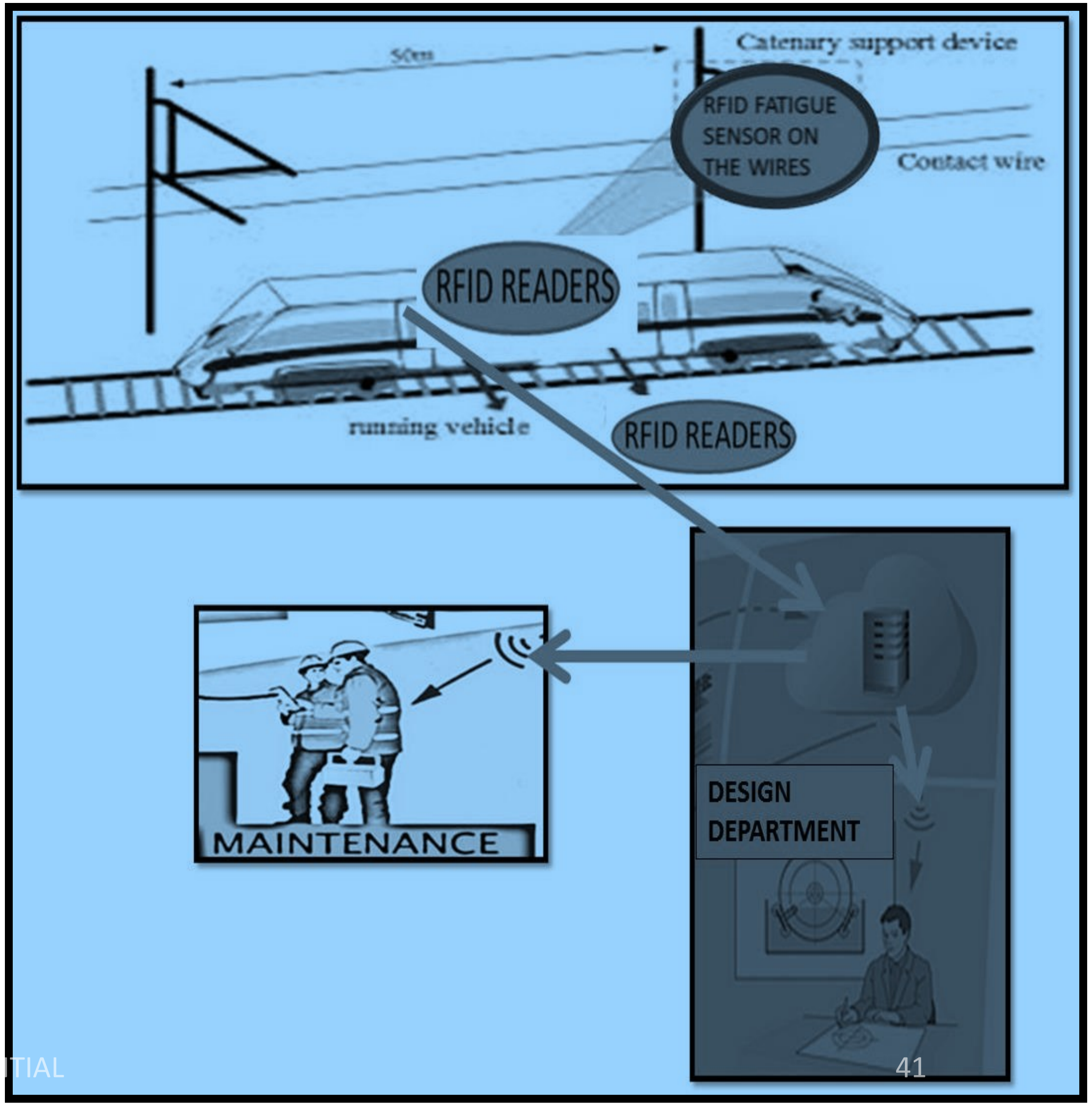
A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks (RAILWAY APPLICATIONS)

- The fatigue strength reliability, one of the important study themes is the strength or fatigue characteristic of each railway system component that is subject to repeated cycling loads during use.
- Fatigue is a microscopic fracture caused by the initiation and propagation of a crack due to a cyclic slip deformation of the size of a single grain, that fatigue occurs even under a stress smaller than the strength characteristic under a static load (e.g., tensile strength), and that it can suddenly lead to a fracture without causing any macroscopic plastic deformation.



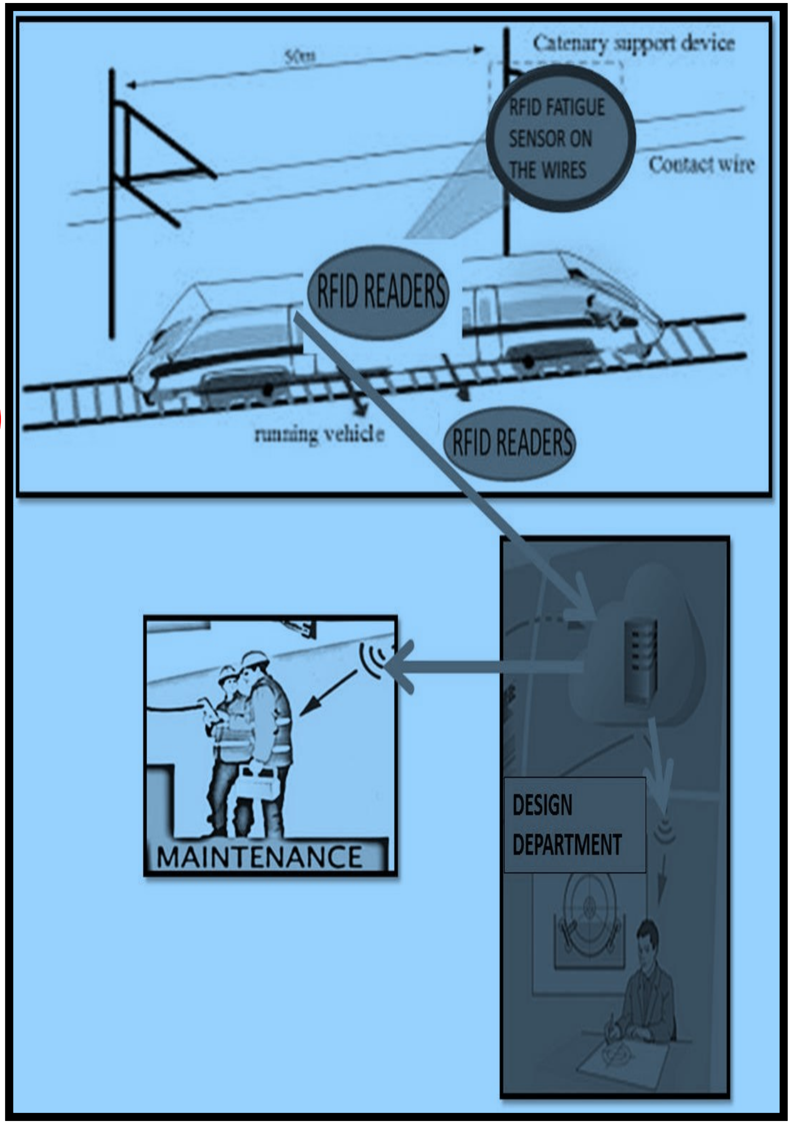
A Novel Wireless Enabled SHM-RFID-IoT Smart Fatigue Damage Sensor (RAILWAY APPLICATIONS)

- **The starting point for car body fatigue analysis is the prediction of dynamic response of the car body structure, which is usually expressed as a stress or strain time history.**
- **A quasi-static stress analysis method is one of standard time domain approaches used to obtain the dynamic stress for fatigue life assessment.**
- **It is a linear elastic analysis that is associated with external load variations.**
- **The main idea behinds this method is that the external load history acting on the structure can be replaced by a static unit load acting on the same location in the same direction as the load history. The quasi-static stress analysis is then performed for each individual unit loads.**



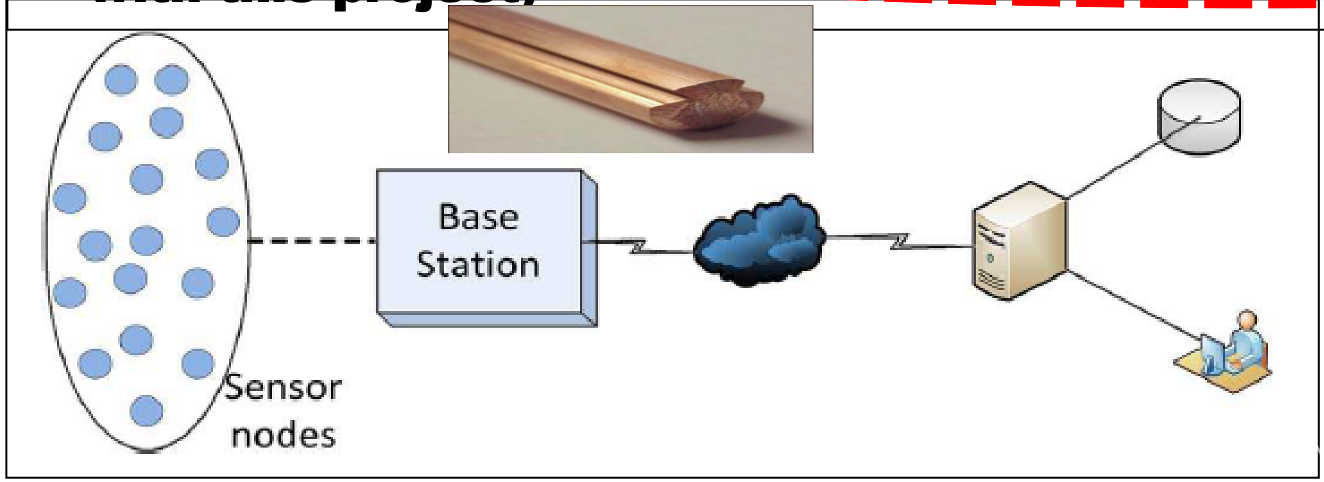
A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks (RAILWAY APPLICATIONS)

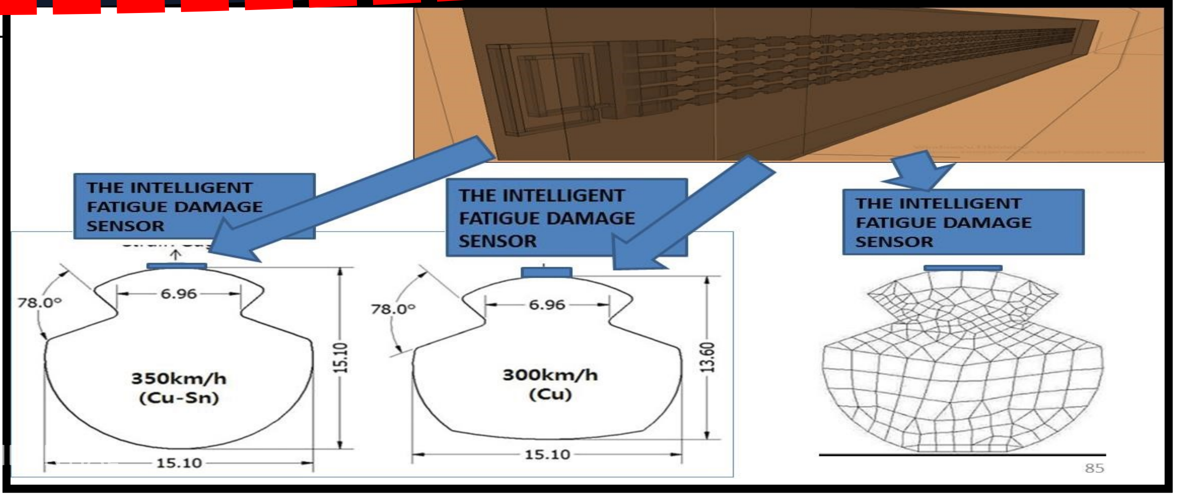
- **Condition monitoring reduces human inspection requirements through automated monitoring, reduces maintenance through detecting faults before they escalate, and improves safety and reliability. This is vital for the development, upgrading, and expansion of railway networks.**
- **Wireless sensor networks (WSNs) are very important for Asset management, condition monitoring, decision support systems, event detection, maintenance engineering, preventive maintenance, railway engineering.**
- **The wireless sensors network technology for monitoring in the railway industry for analyzing systems, structures, vehicles, and machinery.**
- **The practical engineering solutions, principally, which smart sensor devices are used and what they are used for; and the identification of sensor configurations and network topologies.**
- **It identifies their respective motivations and distinguishes their advantages and disadvantages in a comparative review.**



A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks (RAILWAY APPLICATIONS)

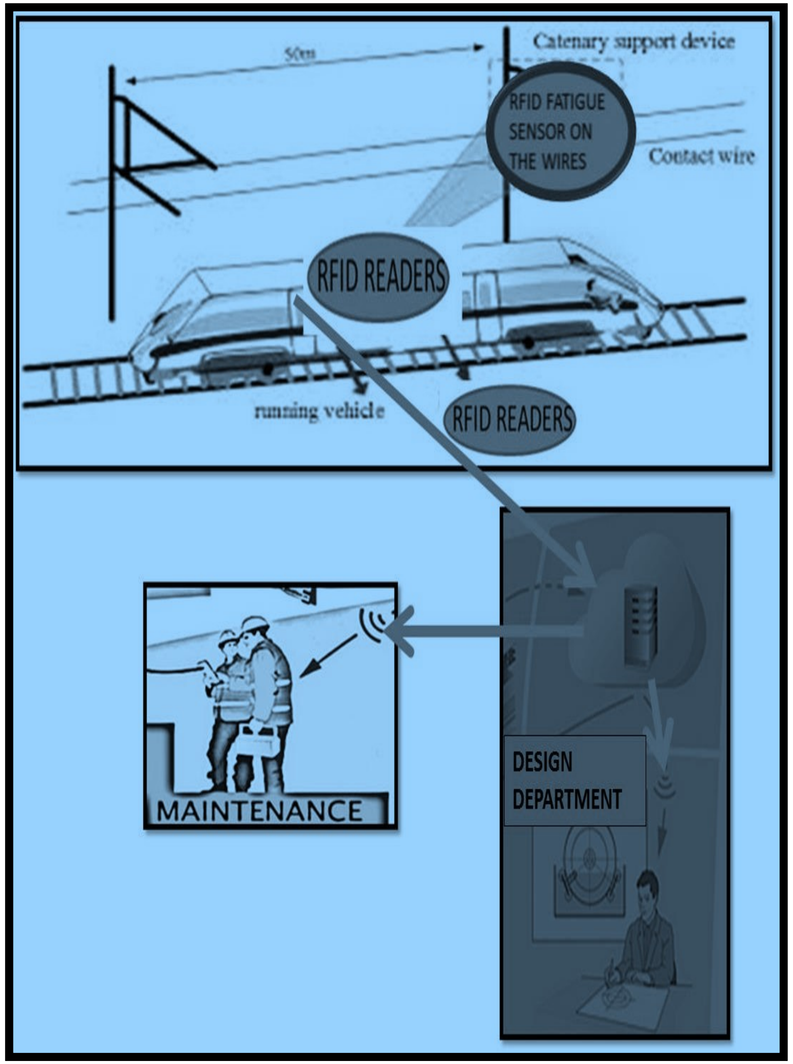
- In recent years, **the range of sensing technologies has expanded rapidly**, whereas sensor devices have become cheaper.
- This has led to a rapid expansion in condition monitoring of systems, structures, vehicles, and machinery using sensors.
- Key factors are the recent advances in **networking technologies such as wireless communication** and mobile *ad hoc* networking coupled with the technology to integrate devices.
- Wireless sensor networks (WSNs) can be used for **monitoring the railway infrastructure such as bridges, rail tracks, track beds, and track equipment along with vehicle health monitoring** such as chassis, bogies, wheels, wagons and CONNECTION WIRES(proposed with this project)





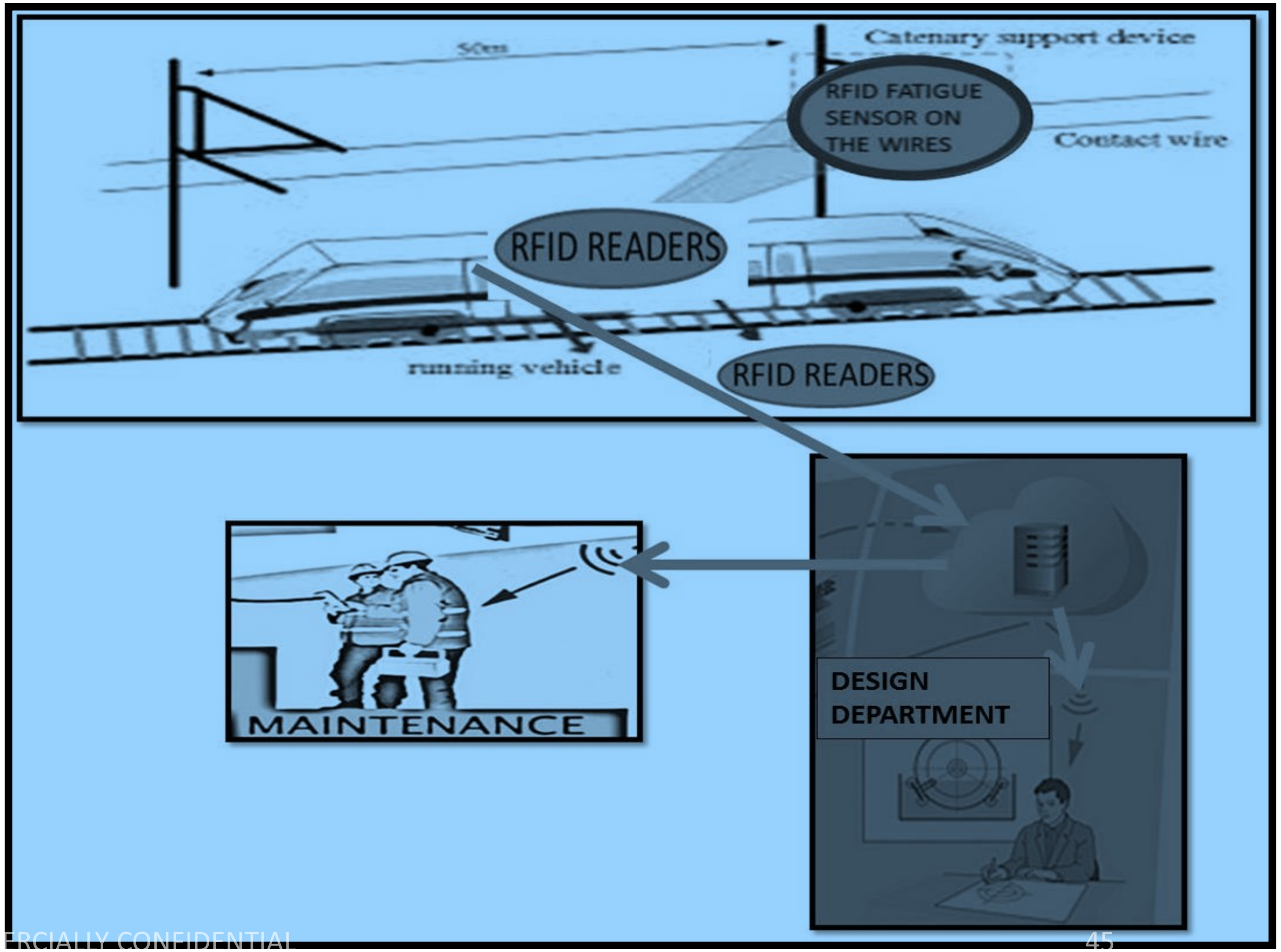
A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks (RAILWAY APPLICATIONS)

- **An INTELLIGENT predictive maintenance strategy for the intelligent structures in rail applications**
- **Development of an integrated predictive maintenance approach using both condition monitoring and historical data, and further support the implementation of predictive models and tools in RAIL APPLICATIONS maintenance programs**
- **Identify methods for the predictive maintenance of freight wagons in order to increase substantially the performance and cost effectiveness of rail transport;**
- **Define a prioritization of RAIL COMPONENTS and sub-systems in terms of their relevance for predictive maintenance;**
- **Investigate failure mechanisms and fault detection methods for the selected vehicle components and sub-systems highly significant to the whole vehicle's LCC and reliability;**



A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks (RAILWAY APPLICATIONS)

- **Select the available condition monitoring and failure history data** for selected critical wagon components and sub-systems, and **develop predictive models** and detect trends in the monitored condition towards a failure state with a time-to-failure prediction;
- **Develop guidelines for maintenance procedures** to implement predictive maintenance practices for the cases studied.
- Perform an assessment of the benefits provided by the developed predictive maintenance strategies.



A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks (RAILWAY APPLICATIONS)

- **Wireless sensor networks (WSNs) can be used for monitoring the railway infrastructure such as bridges, rail tracks, track beds, and track equipment along with vehicle health monitoring such as chassis, bogies, wheels, wagons and POWER CONNECTION WIRES**
- **The economic savings enabled by PM are mainly in terms of reducing the downtime of the wagon and the related opportunity costs**
- **Based on the results of the reliability-driven analysis, important benefits can be expected by the implementation of monitoring and PM in terms of increased reliability and safety.**
- **The effectiveness of the predictive maintenance policy will be assessed on a life cycle cost (LCC) basis. This will allow the selection of the most suitable maintenance strategy that will optimize the overall cost of component during its whole life.**
- **A Decision Support System (DSS) that enables maintenance operators to take decisions about the most adequate maintenance policy considering historical data and real-time (or close-to-real) health data of the component**

A Novel Wireless Enabled SHM-RFID-IoT Smart Sensor Networks (RAILWAY APPLICATIONS)

Wireless sensor networks (WSNs) can be used for monitoring the railway infrastructure such as bridges, rail tracks, track beds, and track equipment along with vehicle health monitoring such as chassis, bogies, wheels, wagons and CONNECTION WIRES

Developing innovative specific failure mechanisms and fault detection methods for selected components based on a prioritization of their relevance for PM;

- **These will be integrated with improved maintenance rules, limits and procedures, resulting in an integrated predictive maintenance procedure.**
- **A tool for maintenance policy optimization, able to use health monitoring information to define an optimal maintenance policy**