A Comparative Study on Defect Detection Techniques in Rail Track Inspection

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ABSTRACT

Railway transportation is the major source of commercial mode of transportation in India which is the denser network of transportation. For smooth operation of railway, it is mandatory for inspection and maintenance of rail track frequently. Traditional inspection technique consists manual inspection of the rail track with the human help which consumes more time and money. The percentage of error occurring during manual inspection is high due to human error. Hi-rail inspection vehicle are not used frequently they are used once in a month or once in a half year. The lack of high rail inspection car for every sub region causes the inspection in a very slower fashion. The need of the hour is to find the technique which covers the following aspects like low human interruption, cost-effective and least amount of error while inspection. For improving the inspection rate in a rapid fashion with minimal amount error and very often in every region advanced technique has been improved in this digital era. In this paper we cover all the techniques involved in the inspection of rail track with time consumption, inspection aspect and the cost involved in each technique. The comparative study between each and every technique is discussed in this paper and the concluded result for the comparative study gives the solution for rail track inspection as interconnect the technique for obtaining better results with minimal error and high standard of inspection.

KEYWORDS: Railway track inspection, Inspection Car, Manual Inspection, Digital Techniques.

INTRODUCTION

Indian railway is the fourth largest railway network in the world with a track length of 68,155 km. Indian railway runs 13,523 passenger trains daily and 9,146 freight trains daily [1]. So,rail maintenance, rail inspection is an important process. It should be periodically inspected or maintained to avoid dangerous situations. In Indian railway mostly rail inspectionis done by manual method and some NDT techniques are used to inspect the rail. But mostly manual method is followed. Gang man who inspects the rail track daily by walking. NDT technique are used in Indian railway but they are not inspected on a regular basis.

In manual inspection Every portion of Permanent Way inspected daily on foot. The types of patrolling are called Gang patrol. During heavy rainfall, hot weather and patrolling at a vulnerable locations and cold weather patrolling becomes a risky work. To protect train against tampering with track and obstruction on the line security patrolling is done. Gang man are facing accident, hit by trains while on work.So,a new process or an automation process is needed to inspect rail tracks.

Existing System

From the beginning of Indian Railway, Manual inspection method is followed. Still now Manual inspection is the major inspecting method in rail track inspection. Itis carried out by a group of people called Gang man and this process is called as gang patrolling. Everyday gang man used to walk through out the rail track and inspect the rail track visually. Manual gang man inspection is the hardest way of inspection. They inspect the rail track under an extremeweathercondition. After evolution of Modern electronics identification usingNDT is proposed to inspect the rails. Inspection train and inspection cars are used to inspect rail track. NDT equipment's used in the equipment cars used only when the new track is laid and then it is used over a period when freight trains crosses with heavy load over a period of time. It is controlled by computer inside the inspection car and the inspected data are stored, processed and then concluded where to repair manually. This process iscarried out very often. Inspection is carried once over a five-year period in passenger train area and three year once in freight train area.

Rail Track Defects

Railway track defects are divided into two main divisions namely Internal Defects and Surface Defects. These defects may exist in thehead and base of the track. The commonly occurring defects in the railway track majorly caused by high-speed rail over the speed of 80 kmph causing the Rolling Contact Fatigue produced due to high friction contact of wheel to the track.Next set of defects occurred due to the change in climatic condition. Humidity with increased temperature increases the chances of various damages in rail tracks. Sun- Kinks and brokage in track is more dangerous than the loose ballast and the growth of vegetation.

Rail Track Inspection Methods are either contact-based which are known as NDT (Non-Destructive Testing), or noncontact based methods which is based on analysing images or videos of the rail-track.

• Contact-based (NDT):

1. Ultrasonic Inspection: this method can detect deep internal defects, but fails to detect surface and near surface defects.
2. MFL (Magnetic Flux Leakage): this technique can detect near surface defects such as RFC, but fails to detect deep internal defects.
3. Eddy Current Inspection: this technique is based on magnetic fields; therefore, similar to MFL, this technique can detect surface defects, but fails to detect deep internal defects. To overcome this shortage, hybrid solutions combining both ultrasonic and eddy current inspections are available.
4. Acoustic Emission Inspection: this method is common with steel rail tracks, where it is used to detect crack's growth and accumulation as well as source of crack localization.

• Non-contact-based:

Visual Inspection: this technique is the most efficient technique used for surface defects detection. It is based on high-speed cameras which capture images of the railway tracks to be processed later based on pattern recognition of the captured images; therefore, it is economical and time saving, but requires higher computational time.

COMPARATIVE STUDY.

Various methods are used to inspect rail track. This comparative study has been made through technique used in rail track inspection. Various technique has been explained and compared.The below all methods are robotic process which is used to inspect rail track. Each method uses different sensors to identify defects. The listed below methods will reduce human power, cost and implies automation in rail track inspection. Every method compared and explained below.

The First method with IR sensor,Fatma and Nath proposed a system for train track monitoring using IR sensor to identify the defects and derailment in track [7]. The system is controlled by ARM processor and the defect data are transferred through communication of Zigbee which is a wireless data transmission which sends data to sub-station and the data is cross-checked. The main element, IR sensor is used to inspect rail track. The IR sensor can only detect breakage between the rail track. AndKuthe proposed system of rail transport [14] they used IR sensor controlled by AT mega micro controller, motor driver controller, they have been using.The IR sensor can only detect breakage between the rail track.Lad, P &PawarM[15] they used components like DC

motor, wheel, GPS, GSM, and passive infrared sensors and with ultrasound waves. As like all robotic system, this system also detects only breakage in rail track.Niranjane, Vaishali B performed a railway track fault detection using a robot through running it on the track [21]. IR sensor in the robot detects the defect on the track and transmits the information using zigbeemodule and Arduino which provides network for wireless sensor. Further the receiver in the control station receives the information and displays on the monitor with an alarm, which alerts the control station officers to take remedial action for the defects.Krishnaperformed a railway track inspection using IR sensor and Bluetooth [12]. The inspection robot consists of two IR sensors used to detect crack on the railway track and transmits signal to the Arduinoand the location of the crack recorded using GPS module.

Inspection with ultrasonic sensor, Mahfuzproposed crack detector robot [20] this is for the safety and reliability which is considered as one of the main issues at all transport system, particularly in railway. They use ultrasonicsensor which is controlled by Arduinomega.The ultrasonic sensor has limitation in speed and identification of small size breakage in rail track. Deokar performed a rail track inspection and monitoring by ultrasonic sensor based on IoT [24]. In this system Raspberry Pi is used to control the overall operations. The ultrasonic sensor detectsdefect in rail trackand then Raspberry Pi transmit information to the control centre and also sends the exact location of the defect using GPS module by the principle of IoT. Iyer designed a multirobot-based fault detection for railway tracks [9]. Which is capable of identifying cracks, squats, corrugations, and rust. And these parameters are identified by ultrasonic sensor and Pi camera. The data given by sensors and camera which are processed by open CV and deep learning algorithms. The identified defects are sent to control station through could storage system. The overall system controlled by Raspberry Pi and powered by rechargeable battery.This process includes sensors and camera to identify different parameter in the rail track.

Chellaswamy proposed a system for track health monitoring [5]. The system works under MEMS accelerometer which identifies the defects in the track and the defects is processed PSO algorithm. And the defects data is sent to central office through IoT and the position of the defect is noted by a GPS system. The MEMS accelerometer fixed in axle of a bogie or in a car. The overall system is controlled and processed by Raspberry Pi. The MEMS accelerometer detects defects when any change in variable assigned to it. It has good function and accuracy at low speed of inspection but it has low accuracy while it is tested in high speed.

Somalraju designed a railway track crack detection robot using LED and LDR sensor [28]. From the sensor the crack in the track is detected and sends signal to the microcontroller and then the

microcontrollersends the location of the defect in the track with the help of GPS and GSM system and location send to a mobile for further human inspection and repair purpose.

LaxmiGoswami performed a crack detection of railway track using smart robot [16]. The smart robot runs on the track by using 12v battery and detects the crack using LED and photodiode as sensing device which transmits the signal to microcontroller and then transmit signal to the LCD monitor which displays the number of cracks detected and the location of crack is registered by GPS module.

All above mentioned methods are robotic process used to inspect rail tracks. Which helps in reduce in man power, cost, real time monitoring, automation in inspection and frequent inspection are achieved

Author Name	Sensor Used	Controller
Fatma (2019)	IR Sensor	ARM processor
Mahfuz (2017)	Ultrasonic Sensor	Arduino
Kuthe (2015)	IR Sensor	AT mega micro controller
Chellaswamy	MEMS Accelerometer	Raspberry Pi
Lad (2016)	IR & Ultrasound Sensor	Micro Controller
LaxmiGoswami (2019)	LED - Photodiode	ARM processor
NIRANJANE (2018)	IR Sensor	Arduino
Krishna (2017)	IR Sensor	Arduino
Prof.S. B. Deokar (2018)	Ultrasonic Sensor	Raspberry Pi
Somalraju (2012)	LED & LDR	Micro Controller
Iyer (2020)	Ultrasonic Sensor	Raspberry Pi

(i) Hardware used in Autonomous Process

The following method are done by Non-Contact based inspection. Which are called vision inspection done by Camera integrated with some software.Li Y performed a rail component detection using a real-time automatic vision-based rail inspection system [19]. Which performs inspection at 16km/h with a frame rate of 20fps. This system precisely detects the rail components such as ties, tie plate, and anchor with high accuracy to capture the images point grey dragon fly2 camera is used quantitative analysis performed on a large video data set captures with different track and lightning conditions, has demonstrated very good performance on rail component detection.

Resendiz proposed computer vision inspection and this computer vision has recently been applied to several railroad applications due to its potential to improve efficiency [25]. The main things are tracks inspection, components, Related work in spectral estimation. Detecting and segmenting periodically occurring ComponentsAnd experiments component detection on panoramas of the track, Turnout detection, Tie detection and its robustness to noise allows it to effectively estimate periodicity in real – world inspection video and image's. The vision-based inspection faces accuracy problem and it detects more false defects and it can work on high speed.AndSingh M performed an automated video analysis technique for rail track inspection [27]. This process identifies the missing clips and blue clips. Blue clips represent the new clips which is replaced for damaged clips. The camera capture video images and transmits to the software which used for analysis of defect, after the defect is confirmed this will automatically give an information to an engineer to rectify the defect on the track. The defects in fastener are detected in a high accuracy than other camera-based inspection method. Huggins performed scheduling rail track maintenance to minimize the overall delays. And they took the maintenance activities like Rail grinding, Rail replacement, tapping, track stabilization, and ballast injection. They tested nearly 89km long and 30 trains on the busiest day of the week. These scheduling process helps the track maintenance people so they can easily work and also minimize the traffic between trains.Li,Qproposed rail inspection and it is important task in railway maintenance [18].Framework of image Analysis by Rail track extraction, Contrast enhancement, Defect localization,acquired image are the main steps for the inspection.Experimental results and performance analysis by the parameters of the LN method and then compare the LN method and DLBP algorithm with the related well-established methods. The detection speed of VIS could be further increased if it is paralleled using parallel computing techniques. This camera based visual inspection technique parried with a more stronger computer code to filters the accurate image of defect, it has increased accuracy then normal camera vision inspection technique.

Various Non-Destructive Testing methods are followed in railway industry. Kumar explainednon-destructive testing technique to inspect the rail track [13]. Methods like ultrasonic testing, eddy current testing, Visual testing, Crack detection using satellite imagery, Contrast Enhancement Method. Explained about function and usage of testing at various condition. And explained merits and demerits of every single process and explains about which process suits for certain area of implementation.

Papaelias proposed types of NDT inspection method and future research process in NDT techniques in rail track inspection [22]. Such techniques like Electromagnetic Acoustic Transducers (EMATs) and acoustic emission, Alternating Current Field Measurement (ACFM) sensors, Guided

wave systems, laser ultrasonic, ultrasonic phased arrays. And research works like, combination of two method to improve accuracy. Integration of high camera vision based system with ultrasonic probe testing to get better results.

PhPapaeliasproposed a detailed review about various types of inspection technique [23] like Ultrasonic, PEC, MAD, AEP, Magnetic flux leakage,Automated visual inspection, Radiography, EMAT, Laser ultrasonic, ACFM, AE. And explained about working condition and nature.Future development of technique and adaptation of the technique.Hybrid technique to improve accuracy and speed of testing better than traditional non- destructive examination.

Wojnarowskipreformed a detection of cracked rail and enhancing traction between wheel and rail [31]. The corresponding power supplied to the coils for producing electromagnetic flux. The produced electromagnetic flux routed through the wheel axles, wheels and rails in a closed circuit. When an interruption occurs in a path, the circuit will open resulting in changed flux pattern. The flux pattern variation is detected by a flux sensor and further electromagnetic when loading means for generating an attraction to the rails. This enhances traction between wheel and rail. The surface and near surface crack are easily detectable but at high speed the accuracy gets very low.

Dixon performed inspection of rail track head surface using electromagnetic acoustic transducers [EMATs] [6]. They used Rayleigh wave signals and frequency between (150-200kHz) They identify the measurements of crack depth. These cracks can develop into more serious defect if the crack tips dip's down into the bulk of the rail. The fusion of magnetic method with acoustic method increases the accuracy in the inspection.

Vijayakumarproposed the Non-invasive rail track detection system using microwave sensor [30]. A new crack detection method for rail track which utilizes microwave sensor to inspect the rail surface during the passage of a train wheel. They were designed under the theory of microwave theory, microwave horn antenna, model simulation result by using HFSS, and experiment set up using microwave sensor. This sensor can detect these cracks with the accuracy of the detection.

Author	Method Used	Advantages	Disadvantages	Accuracy
PhPapaelis (2008)	Ultrasonic	Can detect Surface defect and internal defect of rail web and foot.	At high speed, it can't able to detect defect lesser than 4 mm	High at low speed and good at high speed

Chellaswamy (2017)	MEMS accelerometer	Can detect track irregularity	It can't able to detect surface and internal defects.	High
Li (2012)	Visual	Surface Breaking, Defective ballast and defects in rail sleeper are identified.	Internal and external defects Cannot be detected.	High
Vijayakumar (2009)	Microwave Sensor	Surface defects and cracks are detectable.	At highspeed Accuracy of sensor is low	Good
Kumar (2018)	EMAT	Surface defect internal defects of rail head, web, footis detectable.	Low Accuracy at high speed	Good
Kumar (2018)	Satellite Imagery	Can cover more area within less	The detection of crack depends on the quality of Image	High
PhPapaelis (2008)	Eddy Current Testing	Surface defect and near surface defects are detectable	At higher speed less than 4 mm defects can't able to detect.	Good

(ii) Comparison of Non-Destructive testing followed in Railway

CONCLUSION

In this paper, we have presented the various method followed to inspect rail track in railway. And also explained about the types of defects occurs in rail track. A comparative study about techniques used to inspect rail track. Through the comparative study we have understand that every technique has a unique advantage and suitable for specific process. Among these technique hybrid type ultrasonic sensor gives a detailed report of flaw in rail track and with a low speed. And camera based visual technique gives surface flaw detection in a high speed.

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