Inspection of Rails Using Ultrasonic Probe

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Abstract--The detection of critical inherent cracks in the railhead is a major challenge for the railway industry. Conventional inspection methods have proven not to be reliable enough in this context; therefore the aim of this work is to develop an alternative screening method. The approach is to scan a pulse-echo probe along the rail which covers maximum part of rail head. The properties of the dominant surface of rails were determined and a mode suitable for inspection purposes is identified. In order to ensure correct and reliable signal interpretation of ultrasonic wave a signal processing method is developed. The performance of this method was studied on rails containing artificial and real defects. Furthermore, deep defects were detected even with multiple smaller ones in front. The inspection method developed appears suitable for defect detection and could be used to complement existing methods and thus enhance their reliability.

Keywords: Rail tracks, ultrasonic testing, pulse-echo probe, defects.

ULTRASONIC TESTING (UT)

Ultrasonic testing (UT) is a non-destructive inspection method that uses high frequency sound waves (ultrasound) that are above the range of human hearing, to measure geometric and physical properties in materials. Ultrasound travels in different materials at different speeds (velocity). However, the speed of sound propagation in a given material is a constant.

There are several ways that sound travels through a material. One type of sound wave, called longitudinal or compression travels about 330 metres per second in air and about 6400 metres per second in aluminium or in steel at approximately 5960 metres per second.

To perform UT, electrical energy is converted to mechanical energy, in the form of sound waves, by a transducer. The transducer accomplishes this energy conversion due to a phenomenon referred to as the piezoelectric effect. This occurs in several materials, both naturally-occurring and man-made. Quartz is a naturally occurring piezoelectric material. A piezoelectric material will produce a mechanical change in dimension when excited with an electronic pulse. Similarly, this same material will also produce an electric pulse when acted upon mechanically. An example of the common use of piezoelectric materials is found in the electronic lighters available for starting gas stoves, gas grills, cigarette lighters, etc. In these examples, the piezoelectric crystal is squeezed and released suddenly to result in the generation of an electric spark that jumps across a gap to ignite the gas.

MATERIAL TESTING BY ULTRASONIC

Sound in the frequency range of 500 x 103 cycles/sec(500KHz.) to about 50 x 106 cycles/sec. (50 MHz.) is used for "Material Testing by Ultrasonics". It is above the human audible range and hence it is called Ultrasonic. Ultrasonic is the most extensively used NDT method. It has following inherent advantages over other methods.

- Safe
- Gives instant results
- Can penetrate high thickness
- Economical
- Can generate instant "Test Report"
- Can detect majority of types of defects
- Easy to introduce automation

Following are the types and sub-types of Ultrasonic Testing.

Material testing for surface/internal discontinues

1. Detecting discontinuity
2. Locating discontinuity
3. Evaluating discontinuity

4. Diagnosing discontinuity

Wall thickness Measurement

1. Remaining (Residual) thickness measurement.
2. Checking dimensions of a solid object.

Material Characterization.

1. Determining Physical Properties.
2. Percentage nodularity in SG Cast Iron.

A list of methods used to detect flaws in rails:

1. Ultrasound - the most popular method
2. Eddy current inspection - great for surface flaws & near surface flaws
3. Magnetic Particle Inspection (MPI) - used for detailed manual inspection
4. Radiography - used on specific locations (often predetermined) such as bolt holes and where thermite welding was used
5. Magnetic induction or Magnetic flux leakage - earliest method used to locate unseen flaws in the railway industry.

TYPES OF WAVES

1. Longitudinal Waves
2. Shear Waves
3. Surface or Rayleigh Waves

TYPES OF RAILS

- Flanged rail
- Baulk rail
- Barlow rail
- Vignoles rail
- Flanged T rail
- Double-headed rail
- Bullhead rail
- Tangential turnouts
- Grooved rail
- LR55 rail

TYPES OF GAUGES

- Standard Gauge
- Broad Gauge
- Narrow Gauge

2 WORKING PRINCIPLE

TECHNIQUE OF WORKING

A number of techniques have been used in ultrasonic testing for the design of different equipment's. Some of these techniques are:

(1) Frequency modulation.

(2) Pulse echo.

(3) Transmission.

(4) Resonance.

(5) Acoustic range.

on the Indian railway frequency modulation and pulse echo technique only are used and these are discussed in details in subsequent paras

Pulse Echo System

In the pulse echo technique, a pulse ultrasonic beam of a very high frequency is produced by the pulse generator and sent in the rail. At the opposite face, the ultrasonic waves are reflected and the echo is picked up by the crystal transducer. A discontinuously or defect in the rail will also send back the echo. The time interval that occurs between the initial pulse and the arrivals of echo received, the flaw can be detected by the relative position and amplitude of the echo. There may be a number of multiple reflections of the echo but one arising due to fault can easily detected.

ULTRASONIC RAIL TESTING EQUIPMENT

On Indian railway ultrasonic rail flaw detection is carried out with the help of two different types of equipment viz. single rail tester and double rail tester. The single rail tester has been utilised on the Indian railways for over 35 years and the double rail tester is of a relatively recent origin.

Single Rail Tester

Single rail tester is capable of testing only one of the rails at at time is provided with five probes 0^0 and 70^0 backward (b) 37^0 forward (f) and 37^0 backward (b) . The normal probe (0^0) is utilised for the purpose of detecting horizontal defects situated in head, web or foot.

The 70^0 probe has been specially provided for detecting defects in the rail head, the most typical of which is the transverse fissure of kidney fracture 37^0 probes have been provided to find out defect originating from the bolt hole such as star cracks etc. The signal received from the defects by any of the above probe is indicated on the cathode ray tube screen. In order to find out the origin of detection which probe has picked up the defect, provision for eliminating the individual probe operation has been made in the equipment

Single Rail Tester

Double Rail Tester

The double rail tester is capable testing both the rails at a time. However for each rail, only three probes have been provided for present 70o and 700 backward. This equipment, unlike the single rail tester, has multichannel facility the signal received from each probe can be instantaneously distinguished without taking recourses to process of elimination. There are three modes in the equipment of defect indication CRT audio alarm and LED display

The normal probe is provided for detection of horizontal defects and 00 and 700 probes have been provided for transverse defects in the head. For detection of bolt defects the equipment works on the principle of backward drop, which in the event of a bolt whole crack shows reduction in echo-amplitude of the back wall it is also supported by separate audio alarm distinctly different tone and LED.

The introduction of double rail tester has been specifically made for enhancing the productivity of testing and as well as improving the quality and accuracy of flaw detection. Due to pre –calibrated arrangement, frequency setting of the equipment is not considered necessary. 50

Due to frequent misalignment of probes on the fishplate joints and limitations of detection of bolt hole crack having unfavourable orientation and size, it is desirable to display to deploy double rail tester on LWR/CWR

Multi probe Rail Testing Trolley

This is the most common type of equipment used on Indian railway for detecting flaws in the rails. There are two probes normal probe and angle probe, both of which act independently. the probe material used for detection of ultrasonic waves is barium titanate producing and transmitting vertical ultrasonic waves of 4 mega cycles frequency through vertical probe and 2 mega cycle frequency through angle probe. The height of the probe above the rail surface can be adjusted in the holder assembly.

The normal probe is powerful enough to scan the entire rail depth for defects. it can detect longitudinal discontinuities in the head at junction of either web or the foot or web well as cracks from the bolt holes .it cannot, however, detect vertical cracks. the defects from the normal probe are represented on the oscilloscope screen in the form of firm echoes protruding from a baseline. Ordinary, two echoes are visible on the screen, the initial echoes due to part reflection of the waves from rail top and back echo from the bottom of the rail. An echo between the initial and the back echo with the corresponding reduction in the height of back echo is terminated as a flaw and is inductive of the flaw.

The position of the flaw can be known by reading the distance of the intermediate echo from the initial echo which will be the distance of the flaw from the rail top. The probe has 4 barium titanate crystals, each pair acting as a transmitter and receiver. The crystals are inclined so as to give a beam angle of 700 from the vertical in either direction. The angle probe has strength of 2 megacycles per second and the pulse is somewhat weaker than probe. The probe can however detect successfully transverse cracks in the rail head only.

In the case of angle probe also, the defect are seen on the screen of protrusions from the baseline.

As the angle probe up by the operator.

Another angular probe is provided some times at 370 angles to the vertical surface of the rail to detect particularly small star shaped defect emerging from the bolt holes.

SIDE PROBE FRAME:

It is the probe frame which we made with the help of the Indian railway chief engineer Mr Raj Kumar. It is rectangular frame with 3 slots in which 2 are of equal size.

Fig: Side Probe Frame

From above figure we can see the side probing frame. The dimensions of the side probing frame are

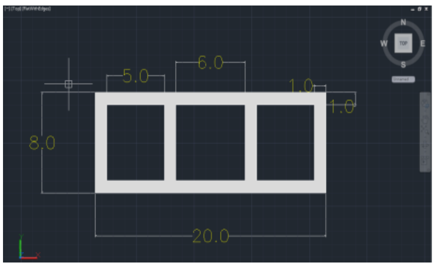


Fig: Front view of side probe frame

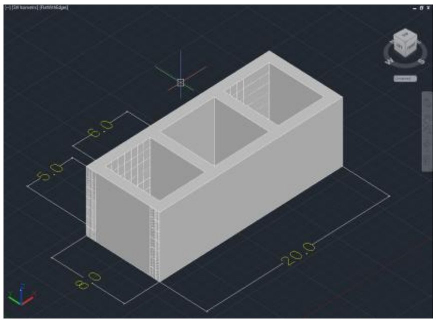


Fig: Isometric view of the side probe frame

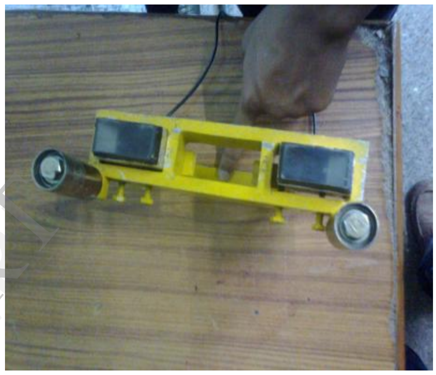


Fig: 700 probes in side probing frame

and the area of rail head scanned by the side probes are shown in below figure

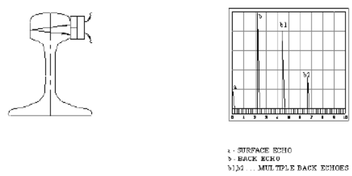


Fig 59: The area scanned by the side probe when no defect is present

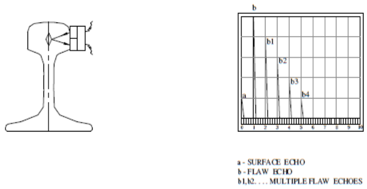


Fig: The defect Area Scanned by side probes

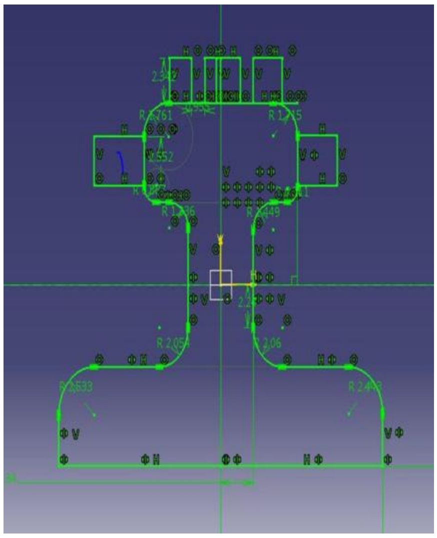
We started the rail testing machine and moving the single rail tester on the track where defects have to be detected.

RAIL TESTER:

The Rail tester placed in the machine and connected to the probes. The machine placed on the track where no crack is present.

WORKING:

Initially the total equipment is placed on the track such that side probe frames are aligned properly to the track. The couplet is on such that it wet total rail head. in this modified method the probes are placed as shown in below figure

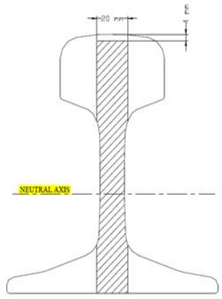


1 – 0^0 NORMAL SIDE PROBE
2 – 70^0 GAUGE SIDE PROBE
3 – 70^0CENTRAL PROBE
4 – 70^0 NON GAUGE SIDE PROBE
5 - 0^0NORMAL SIDE PROBE
6 - 0^0 NORMAL CENTRAL PROBE

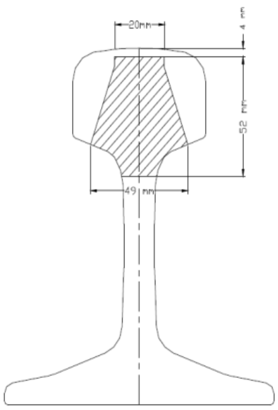
Here the 5, 1 are side probes and remaining 4,3,6,2 are top surface probes.

The areas scanned by each probes are

0^0 Normal probe:



70^0 probe:



70 degree Side probes:

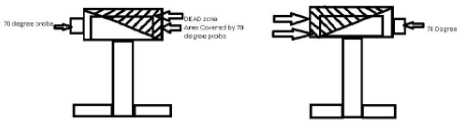


Fig: Area covered by side probes, it completely covers the dead zone

The testing was on the below rail track which had a flaw to detect the intensity of flaw which was classified under observation.

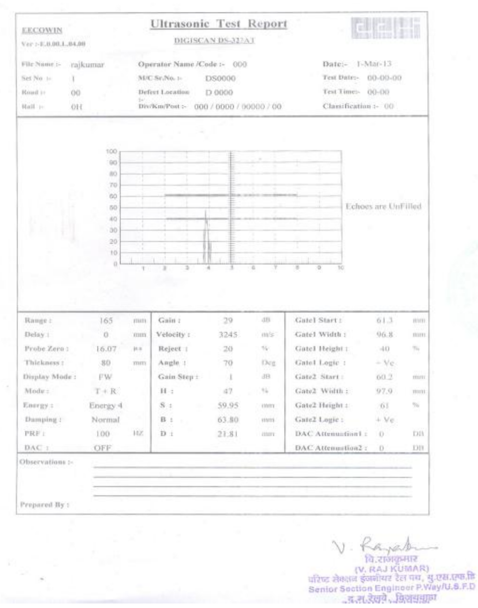
Initially we did with the present process as show in below figure

Fig: Testing of defect using normal process

Then we tested with the modified process to the efficiency of the modified process than the present process.

Fig: Modified process on the defect of rail

This is the graph for the present process



EECOWIN
Ver :-E.0.00.L.04.00

Ultrasonic Test Report
DIGISCAN DS-322AT

File Name :-	rajkumar	Operator Name /Code :-	000	Date:-	1-Mar-13
Set No :-	1	M/C Sr.No. :-	DS0000	Test Date:-	00-00-00
Road :-	00	Defect Location :-	D 0000	Test Time:-	00-00
Rail :-	0H	Div/Km/Post :-	000 / 0000 / 00000 / 00	Classification :-	00

Range :	165	mm	Gain :	29	dB	Gate1 Start :	61.3	mm
Delay :	0	mm	Velocity :	3245	m/s	Gate1 Width :	96.8	mm
Probe Zero :	16.07	µs	Reject :	20	%	Gate1 Height :	40	%
Thickness :	80	mm	Angle :	70	Deg	Gate1 Logic :	- Ve	
Display Mode :	FW		Gain Step :	1	dB	Gate2 Start :	60.2	mm
Mode :	T + R		H :	47	%	Gate2 Width :	97.9	mm
Energy :	Energy 4		S :	59.95	mm	Gate2 Height :	61	%
Damping :	Normal		B :	63.80	mm	Gate2 Logic :	+ Ve	
PRF :	100	HZ	D :	21.81	mm	DAC Attenuation1 :	0	DB
DAC :	OFF					DAC Attenuation2 :	0	DB

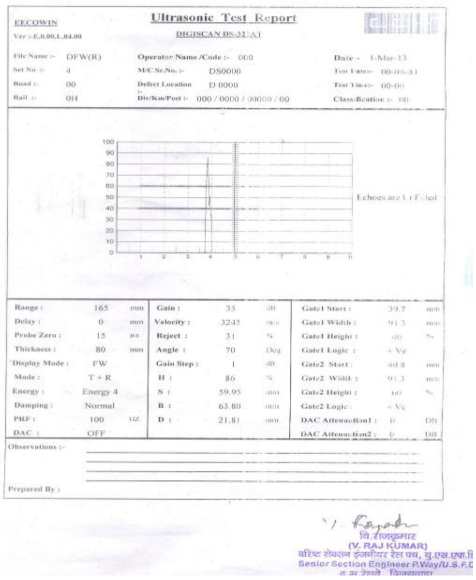
Observations :-

Prepared By :

(V. RAJ KUMAR)
Senior Section Engineer P.Way/U.S.F.D

Graph 1 : Graph for present process

This is the graph obtained for modified process



Ultrasonic Test Report

DIGISCAN DS-322AT

EECOWIN

Ver :-E.0.00.L.04.00

File Name :-	DFW(R)	Operator Name /Code :-	000	Date :-	1-Mar-13
Set No :-	4	M/C Sr.No. :-	DS0000	Test Date:-	[illegible]
Road :-	00	Defect Location :-	D 0000	Test Time:-	[illegible]
Rail :-	0H	Div/Km/Post :-	000 / 0000 / 00000 / 00	Classification :-	00

Range :	165	mm	Gain :	35	dB	Gate1 Start :	39.7	mm
Delay :	0	mm	Velocity :	3245	m/s	Gate1 Width :	91.3	mm
Probe Zero :	15	µs	Reject :	31	%	Gate1 Height :	40	%
Thickness :	80	mm	Angle :	70	Deg	Gate1 Logic :	+ Ve	
Display Mode :	FW		Gain Step :	1	dB	Gate2 Start :	40.8	mm
Mode :	T + R		H :	86	%	Gate2 Width :	91.3	mm
Energy :	Energy 4		S :	59.95	mm	Gate2 Height :	60	%
Damping :	Normal		B :	63.80	mm	Gate2 Logic :	+ Ve	
PRF :	100	HZ	D :	21.81	mm	DAC Attenuation1 :	0	DB
DAC :	OFF					DAC Attenuation2 :	0	DB

Observations :-

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The obtained graphs shows that it is the serious inherent defect in the rail through modified process which was classified under the observation in the normal process. This shows that the present system failed to detect the flaws effectively than our modified process.

CONCLUSIONS:

From this project we have overcome most of the limitations and achieved following:

• A 5 mm deep layer from rail table can be tested as it falls in the dead zone of the probe.

• Ultrasonic beam is directed towards the flaw in any angle.

• Similarly, if the cracks are propagating vertically downwards or upwards, detection is possible.

• Cracks lesser than 0.8mm size can be detected.

This is proved by above graphs which are provided.

So this process is effective and can be implemented in railways for proper detection of cracks in rail tracks.

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