Application of Advanced Techniques and GIS in Railway Safety Management

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Abstract— Railway industry has a valuable role in economic development of each country. India's massive rail network is hit by an average of 300 accidents a year. A number of locating and positioning sciences and technologies have been employed to efficiently handle railway accidents. Among them geographical information system (GIS) as a locating and global positioning system (GPS) as a positioning system have been considered as highly efficient. GIS is implemented for defining geo referenced locations, storing attribute data and displaying data on maps. Safety management in railway is required to avoid or mitigate damages. The railway industry is adapting various new tools and techniques to yield high productivity, to attain safety and sustainability. The damages can be avoided by accident prevention and development of a system to predict before the occurrence of accidents. The damages can be mitigated by reduction of negative effects of accidents after its occurrence through proper emergency and management services. Being closely associated with passenger and goods transportation; railways have high risk associated with them in terms of human lives and cost of assets. New technologies for railways and better safety measures are introduced time to time but still accidents do occur. Thus, a proper strategy is required for maintenance and inspection of tracks. A procedure for digitization of rail defects is then developed in integration with a GIS tool (Gram++). Five aspects are considered during site-layout planning: (1) Study of advanced techniques used in detecting cracks in rails. (2) Selection of a site to carry out crack detection. (3) Identification of cracks using USFD testing. (4) Digitization of selected site from Indian Rail map using GRAM++. (5) Preparation of the GIS based model. (6) Cost analysis for estimation of quantities of materials required for rail repairs and replacement.

Key words: Geographic Information System (GIS), Ultrasonic Flaw Detection (USFD), D-Marked Rails, Map Digitization, Vector Analysis, Time and Cost Management

I. Introduction

The rail industry is receiving more global attention than it has for many years. Rail testing, although a small component of the industry is also seeing an increase in interest (Donald Uzarski, Sue Mcneil 1994). The Indian Railways has the world's fourth largest railway network in the world, after that of the United States, Russia and China. The railways carry over 20 million passengers and 2 million tons of freight daily. The existing conventional signaling system most of the times relay on the oral communication through telephonic and telegraphic conversations as input for the decision making in track allocation for trains. There is large scope for miscommunication of the information or communication gap due to the higher human interference in the system. This miscommunication may lead to wrong allocation of the track for trains, which ultimately leads to the train collision. The statistics in the developing countries showing that 80% of worst collisions occurred so far is due to either human error or incorrect decision making through miscommunication in signaling and its implementation. To achieve the safety necessary steps should be taken to simulate train movement, accidents and rail accident management system. The major problems in the simulation include: (1)The lack of appropriate information, (2)The problem of making real accident scene environment due to human and cost issues, (3)Problems in performing a comprehensive test on the system.

II. Crack Detection techniques

Any defect in rail or any material which may lead to fracture or breakage is called a flaw. The development of flaws is inevitable. The two main reasons for occurrence of flaws are the inherent defects in the rails generated during manufacturing and fatigue of rails due to passage of traffic. With increase in the axle loads and the speeds of the trains, the rail stresses are increasing which in turn is likely to result in high defect generation rate in the rails.

A. Causes of Defects

1) Material defects originating during the manufacturing process.
2) Residual stresses induced during manufacture (cooling, rolling, gas pressing and straightening).
3) Defects due to incorrect handling e.g. plastic deformation, scoring, denting, etc.
4) Defects associated with faulty welding i.e. gas pores, lack of fusion, inclusions, cracks etc.
5) Excessive thermal stresses due to variation in rail temperature beyond specified limits.
6) D-Marked rails (Dispensation with respect to degassing)

B. Nature of Defects

1) Horizontal crack in head
2) Vertical-longitudinal split in head
3) Horizontal crack at head web junction
4) Horizontal crack at web-foot junction
5) Vertical longitudinal splitting of the web

C. USFD Testing

Broken rails are the most frequent cause of freight-train derailments. Consequently, reducing their occurrence is a high priority for the rail industry. Current practice is to periodically inspect rails to detect defects using non-destructive technology such as ultrasonic inspection. Determining the optimal rail inspection frequency is critical to efficient use of infrastructure management resources and maximizing the beneficial impact on safety. Minimization of derailment risk, costs of inspection vehicle operation, rail defect repair, and corresponding train delay are all affected by rail inspection frequency. (Xiang Liu, Alexander Lovett, S. Tyler Dick, M. Rapik Saat and Christopher P. L. Barkan, 2014)

On Indian Railways, flaw detection by ultrasonic is carried out with the help of two different types of equipment viz. Single rail tester which is capable of testing only one rail at a time and double rail tester which is capable of testing two rails at a time. The instrument is provided with seven probes:

1) 0º Normal probe
2) 70º Centre Forward (CF)
3) 70º Centre Backward (CB)
4) 70º Gauge Face Forward (GF)
5) 70º Gauge Face Backward (GB)
6) 70º Non-gauge face Forward (NGF)
7) 70º Non-gauge Face Backward (NGB)

The normal probe (0º) is utilized for the purpose of detecting horizontal defects situated in head, web or foot. The 70º probe has been specifically provided for detecting defects in the rail head, the most typical of which is the transverse fissure.

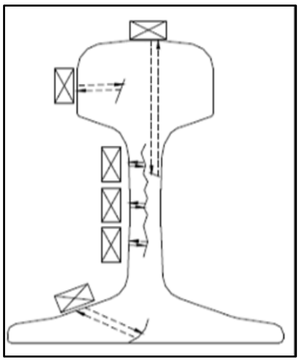

Fig. 1 Probe Arrangement

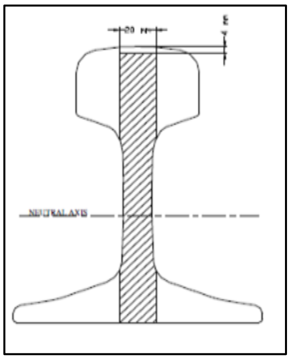

Fig. 2: Area covered by 00 probe

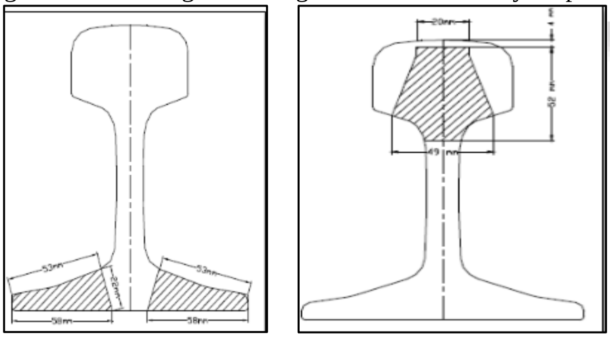

Fig. 3: Area covered by 700 probe (Manual for Ultrasonic testing of rails and welds, 2012,Research designs and Standards organization, Lucknow; Fig 2A)

The procedure laid down for ultrasonic testing of rails is broadly divided in the following steps:

1) Visual inspection of Equipment and accessories
2) Calibration of equipment
3) Sensitivity setting of the equipment and probes
4) Checking of the equipment characteristics
5) Testing and interpretation

In the case of ultrasonic, we are sending a beam of ultrasonic energy into the rail and looking for the return of reflected or scattered energy using a collection of transducers. The amplitude of any reflections together with when they occur in time can tell us about the integrity of the rail. Since defects are not totally predictable, we send in energy at several different incident angles in order to ensure that we maximize our chances of finding any detrimental features. (Robin Clark, 2003)

During testing, proper alignment and functioning of probes is maintained. The USFD machine is moved on the rails so that the sound waves pass through the rails. And the noise pattern appears on the screen. The locations found defective are recorded. The proper record of testing, observations, echo pattern and echo amplitude of defects is maintained as below:

Section Line… Km from Km to…. Dateof testing…	S. No.	Loca-tion (Km)	Roll-ing mark	Rail/weld No.& LH/RH	Defect position (head/ web/foot)	Defect indicated by ($0^0/70^0/45^0$Probe)	Nature of echo (shift/fixed)	Echo amplitude/ Travel		Classification		Remarks
								Previous	Present	Previous	Present	

Table 1: Observation of USFD testing (Manual for Ultrasonic Testing of Rails and Welds)

III. Application of GIS

GIS can be a very powerful tool in emergency management. This technology has the ability to capture the data by digitizing, scanning, digital imagery, or aerial photography; to store the data; to manipulate the data; to form data queries; to analyse the data; and most importantly, to visualize the data. In other words, GIS technology brings to the user the ability to integrate, store, process, and output geographic information. This system takes a multitude of data from numerous sources and graphically displays the information. (Ertug Gunes and Jacob P. Kovel 2000)

The GIS technology helps in the interaction of multiple participants such so that the problem can be approached in a more comprehensive and systematic way. GIS applications are tools that allow users to create interactive queries, analyse spatial information, edit data in maps, and present the results of all these operations. Modern GIS technologies use digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization.

A. *Spatial Database*

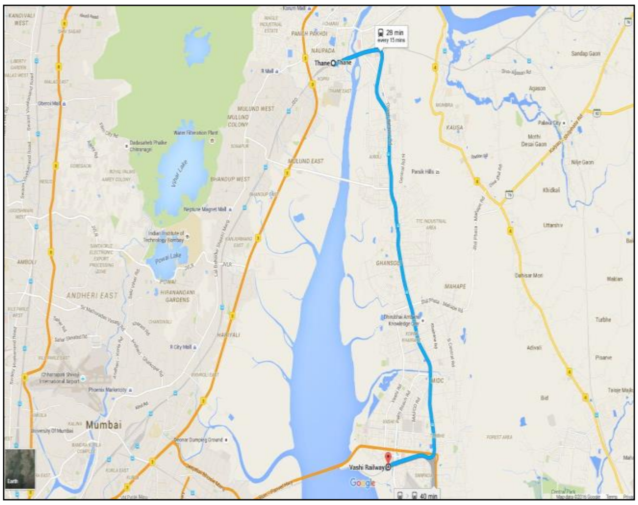

Fig. 4: Thane Vashi Rail map

The spatial data attributes can be metrical or topological. Metrical attribute include position, shape and size while the topological attribute are those which describe the characteristics such as connectivity and adjacency. Spatial entities are conventionally divided into points, lines, polygons and surfaces. Polygons are perhaps the most frequently encoded features in GIS.

To carry out the digitization process Thane-Vashi rail map is used. Any map before being digitized in GRAM++, it has to be registered with its ground coordinate system. It includes specifying scale, projection, details, latitude, longitude etc. of the map. The map should ideally have these features along with the orientation.

1) Details of the map

1. Scale of the map: 1:5000
2. Projections: X- 17^{0}00’00” N Y-70^{0}00’00”E
3. Ground Coordinates:

The four coordinates which are marked as tick marks are as follows:

Sr. No.	Reference point	Latitude	Longitude
1	Malad Railway Station	19^{0}11’14”N	72^{0}50’56”E
2	Bandra Railway Station	19^{0}03’17”N	72^{0}50’26”E
3	Kharghar	19^{0}03’23”N	73^{0}04’03”E
4	Datiwali Railway Station	19^{0}11’13”N	73^{0}03’32”E

Table 3: Ground Coordinates

These four points are marked as tick marks with minimum error in map edit module of GRAM++.

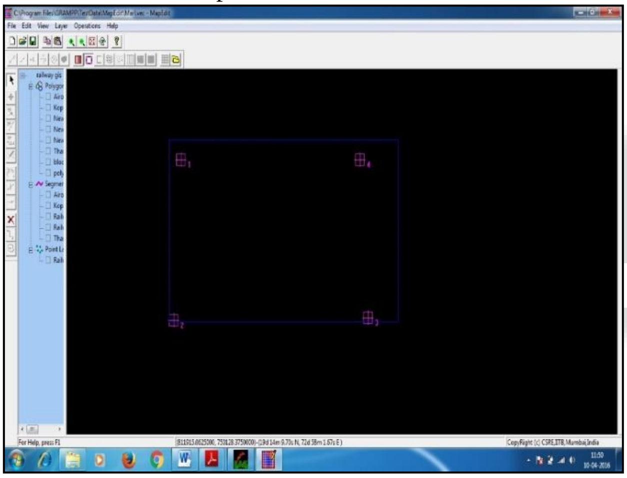

Fig. 5: Tick marks within acceptable limits

The map digitisation is carried out by using layers. The railway line is digitised as segment layer and railway stations are digitised as point layer as shown in fig. 6.

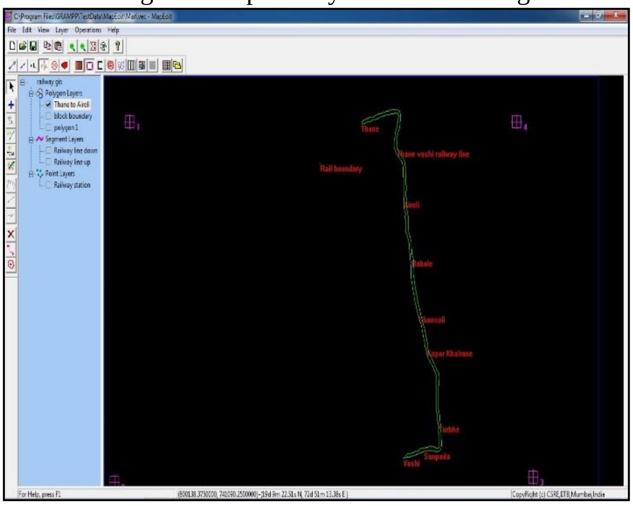

Fig. 6: Digitised Thane Vashi rail map

In the process of editing of a digitized .vec file the layer wise cleaning is carried out. The layer is checked for errors and again cleaned by removing errors. After cleaning the process of polygon formation and polygon labelling is completed.

B. Non-Spatial Database

In addition to the spatial database each of the entity has a number of other important attributes associated with it. These attributes may be land use pattern, population of region, type of soil, etc. If spatial data represents boundary of village, then each entity will have a number of corresponding non spatial attributes such as population, infrastructure, land use etc. In this case the data related to rail classification, location of defect, types of probe used are included. This database can be organized using database management software and proper linkage should be established between the spatial and non-spatial database.

The data collected from Ultrasonic Flaw Detection Testing is added as attributes in Microsoft Access.

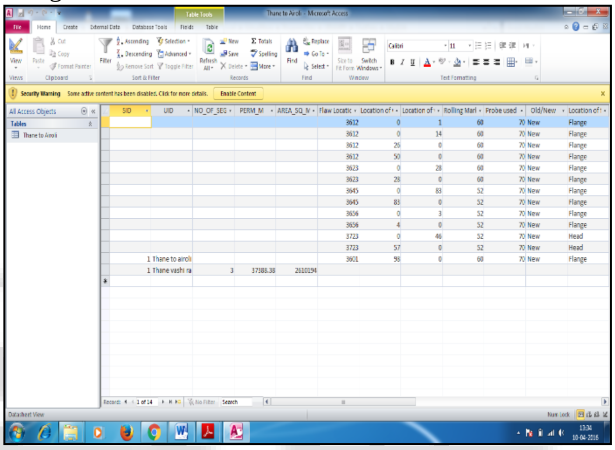

Fig. 7: Database in Microsoft Access

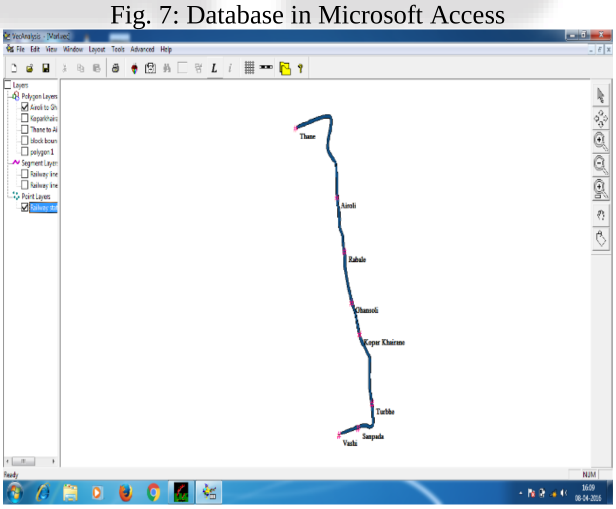

Fig. 8: Vector Analysis

IV. TIME AND COST MANAGEMENT

Application of GIS using GRAM++ helps to reduce the time required for the analysis of defects in rails. As soon as the database is entered and vector analysis is carried out GIS helps to get the exact location of crack and also the intensity of crack. The database helps to get the information about the defects and also helps in decision making. By knowing the intensity of defects, it can be decided that whether it should be replaced or repaired. The cost of replacement or repair is estimated by finding the required quantity and cost of rails in Rs/kg, cost of testing of one weld, cost of welds.

V. Conclusions

This paper demonstrates that Ultrasonic testing of rails is one of the most powerful tools of preventive maintenance of the permanent way of rails. Thus successful performance of rails is based on their resistance to crack initiation and crack propagation. It also shows that GIS is an effective tool in railway safety management. It presents a new process for the development of computer-aided quantity estimate. Application of GIS in Railway safety management helps to reduce time required for analysis as well as cost of maintenance. It proves that GIS is a promising tool for solving problems and thus opens up a new way of thinking in the management of spatial information related to rail safety.

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