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RESEARCH ARTICLE

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SELF - DETECTION OF AXLE CRACKS OF LIGHT WEIGHT FREIGHT CARRIAGES IN REAL TIME

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ABSTRACT: In India conventional freight wagons are generally made of steel, cast iron, iron alloys, aluminum. These metals are heavy which when used to build wagons increases the weight of the wagons. High base weight of wagon means more power is required to pull the wagon, which in turn require more powerful engine. So, the efficiency of operation decreases. Using light weight materials which are cost effective as compared to steel, iron and strength is similar to these conventional metals. Railroad accidents mainly occur in developing countries due to poor maintenance of wheels, axles. Failure or breakdown of axles causes the train to derail and cause accident. Installing the crack detection system integrated with the wheel set will constantly monitor the axle sets for cracks and prior to failure will give warning to the driver and control station. This system will reduce the chance of accidents and damage to both lives and properties.

Keywords—Nonconventional Materials, Wagon, Crack detection.

INTRODUCTION

Generally, in India freight trains are conventionally pulled by a locomotive either electric or diesel. Heavy weight wagons require more effort and utilizes more energy which in turn decreases the efficiency of operation. Another shortcoming is the use of steel, iron and its corresponding alloys to make the wagons instead of using light weight, robust material having same & better properties as of steel & its derivatives. Surface cracks, internal cracks appear within axles, wheels due to fatigue, continuous heavy weight operation and high stress. These cracks if not detected well before fatigue could result in failure of axles which will cause accident. In Indian Railways randomly after certain cycles of operation wagons are inspected for faults manually which is not very efficient in crack detection. So, installing crack detection system integrated with the wheel will detect the cracks in run time, which can prevent accidents due to failure.

DISADVANTAGES OF SOME OF THE IMPLEMENTED TECHNIQUES:

- Using heavy weight materials adds more weight to the carriage and needs more power from the engine.

- Cost of conventional metal is very high as compared to some non-conventional materials.
- Poor maintenance and crack detection technique results in failure and damage to properties.

The disadvantages can be overcome by the technique discussed in details below taking each case separately.

USE OF LIGHT WEIGHT MATERIAL

Typically the freight wagons are made of steel and sometimes stainless steel to reduce corrosion. Earlier iron was used to build the wagons, but due to the corrosive nature of iron , stainless steel was adopted to manufacture the wagons. But, due to the tremendous rise in price of steel, railway started to initiate production of aluminum wagons on a trial basis. Since aluminum is lighter than steel it reduced the tare by 4.2tonnes

Aluminum wagons besides being of a lower cost and having a lower tare weight, also have the advantage of suffering less corrosion in many circumstances. A typical rake with aluminum wagons instead of steel ones would carry almost 240t more goods.

Along with Aluminum, fiber glass sheet can be used to manufacture the wagons, which will further reduce the weight of the wagon and thus increasing efficiency. An indicative comparison follows –

Table I (Properties of steel)

Properties	**Carbon Steels**	**Alloy Steels**	**Stainless Steels**
Density (1000 kg/m3)	**7.85**	**7.85**	**7.75-8.1**
Elastic Modulus (GPa)	**190-210**	**190-210**	**190-210**
Poisson's Ratio	**0.27-0.3**	**0.27-0.3**	**0.27-0.3**
Thermal Expansion (10-6/K)	**11-16.6**	**9.0-15**	**9.0-20.7**
Melting Point (°C)			**1371-1454**
Thermal Conductivity (W/m-K)	**24.3-65.2**	**26-48.6**	**11.2-36.7**
Specific Heat (J/kg-K)	**450-2081**	**452-1499**	**420-500**
Electrical Resistivity (10-9W-m)	**130-1250**	**210-1251**	**75.7-1020**
Tensile Strength (MPa)	**276-1882**	**758-1882**	**515-827**
Yield Strength (MPa)	**186-758**	**366-1793**	**207-552**
Percent Elongation (%)	**10-32**	**4-31**	**12-40**
Hardness (Brinell 3000kg)	**86-388**	**149-627**	**137-595**

Table II (Properties of Aluminum Alloys)

Density	2600-2800 kg/m3
Melting Point	**660 °C**
Elastic Modulus	**70-79 GPa**
Poisson's Ratio	**0.33**
Tensile Strength	**230-570 MPa**
Yield Strength	**215-505 MPa**
Percent Elongation	**10-25%**
Thermal Expansion Coefficient	**20.4-25.0 × 10-6/K**

Chart I

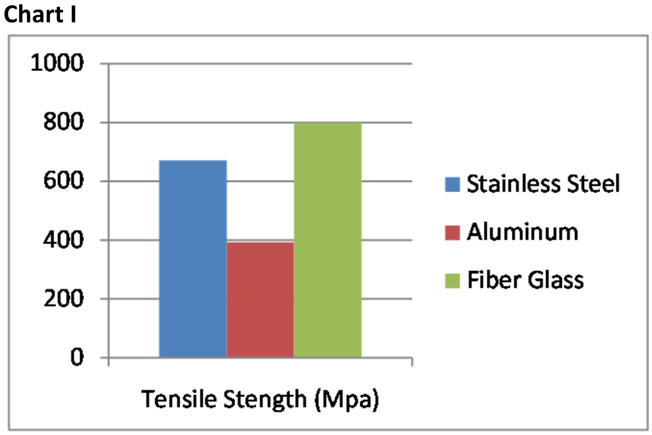


Chart II

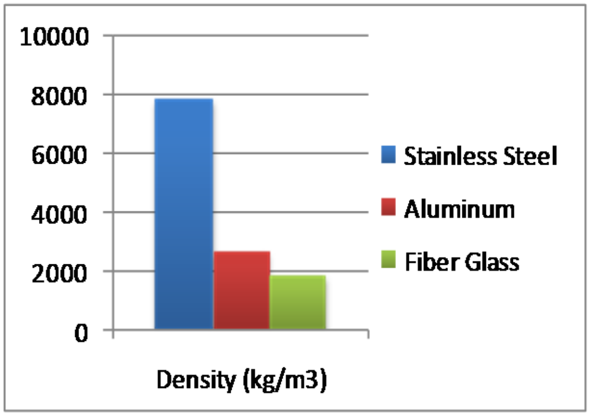


Table III
(Fiber Glass Properties)

Material	Specific gravity	Tensile strength MPa (ksi)	Compressive strength MPa (ksi)
Polyester resin (Not reinforced)	**1.28**	**55 (7.98)**	**140 (20.3)**
Polyester and Chopped Strand Mat Laminate 30% E-glass	**1.4**	**100 (14.5)**	**150 (21.8)**
Polyester and Woven Rovings Laminate 45% E-glass	**1.6**	**250 (36.3)**	**150 (21.8)**
Polyester and Satin Weave Cloth Laminate 55% E-glass	**1.7**	**300 (43.5)**	**250 (36.3)**
Polyester and Continuous Rovings Laminate 70% E-glass	**1.9**	**800 (116)**	**350 (50.8)**
E-Glass Epoxy composite	**1.99**	**1770 (257)**	**410**
S-Glass Epoxy composite	**1.95**	**2358 (342)**	**1912**

PROPOSED MODIFICATIONS

As seen above, physical properties chart of three types of materials has been provided along with a graph comparing the Tensile strength & Density of the materials.

- It is seen that out of Stainless Steel, Aluminum & fiber Glass, stainless steel has the tensile strength a little bit higher than that of aluminum but less than that of fiber glass.
- Similarly, from the density graph it is seen that the density of Fiber glass is the lowest than that of the other two materials.
- If the wagons are manufactured using aluminum alloys or fiber glass, the weight of the wagons will be much less than those made of stainless steel or steel alloys.
- If weight is less , then the efficiency of the engine increases, it requires less energy .
- Fiber glass is totally non-corrosive.
- Cost of making fiber glass is very less as compared to aluminum and stainless steel.
- Less weight means more rapid acceleration.
- Energy required to manufacture fiber glass is far less than the energy wasted in obtaining aluminum and steel from its ores, thus reducing carbon footprint.

Sample Calculation (Approx. Estimation)

From the fig. it is seen that length, l = 12800mm

Width of the wagon, w = 3136mm

Height of wagon (above floor height), h = 1880mm

Surface area for the entire carriage with top open is given by, A = (2xlxh) + (2xwxh) + (lxw)

Or, A = (2x12800x1880) + (2x3136x1880) + (12800x3136),

Or, A = 48128000 + 11791360 + 40140800

Or, A = 100060160 mm2

Or, A = 100.06m2

Now, Cost of stainless steel = 2965US$ / tonne

For a sheet of Gauge = 5 and Thickness = 5.314mm

Weight per unit area = 41.668kg/m2

Therefore, Total steel required (approx.) is given by

N = Weight X Area (A)

Or, N = 41.668 x 100.06

Or, N = 4169.3 kg of stainless steel reqd. (approx.)

Cost = 4.1693 x 2965 $

Or, Cost = 12361.97 $

Now, Cost of Fiber glass ((FRP) Corrugated Sheet) of thickness 5mm/5ply = 3$ per sq. ft.

Area , A = 1077 ft2

Cost of Fiber glass = 1077 x 3$

Or, Cost = 3231$

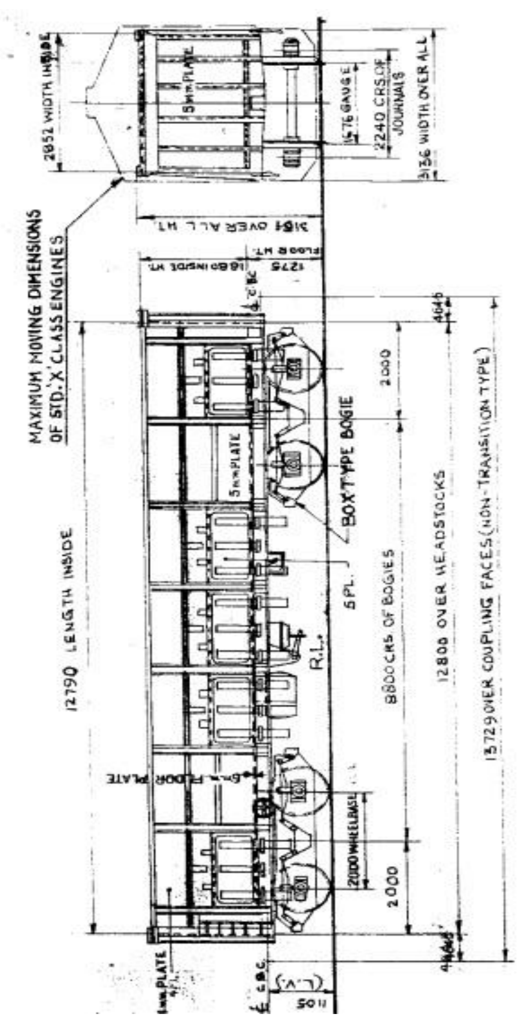
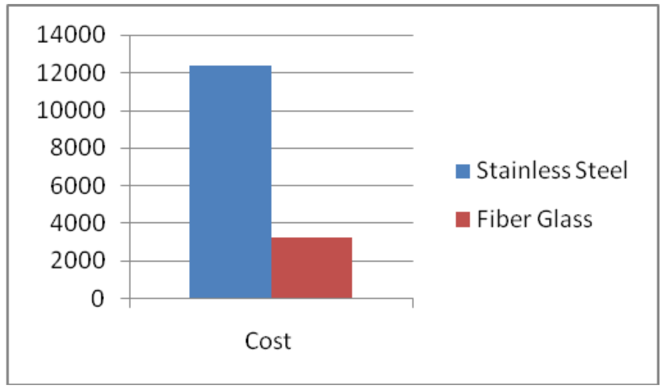


Fig. BCXT Wagon[1]

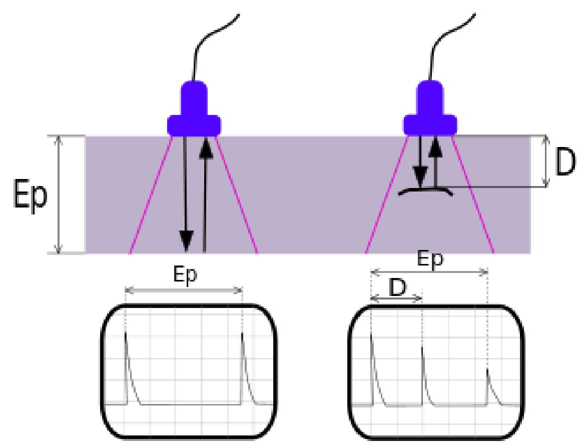


Cost Comparison

Analysis of Result- Under Analysis

CRACK DETECTION SYSTEM- *ULTRASONIC TESTING*

Here very short ultrasonic pulse-waves with central frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz are launched into materials to detect internal flaws or to characterize materials. Ultrasonic testing is performed on steel and other metals and alloys, it can also be used on concrete, wood and composites, albeit with less resolution. It is a form of non-destructive testing used in many industries including aerospace, railways, automotive and other transportation sectors.



Principle of ultrasonic testing. LEFT: A probe sends a sound wave into a test material. There are two indications, one from the initial pulse of the probe, and the second due to the back wall echo. RIGHT: A defect creates a third indication and simultaneously reduces the amplitude of the back wall indication. The depth of the defect is determined by the ratio *D*/*E*p[2]

Working Principle - In ultrasonic testing, an ultrasound transducer connected to a diagnostic machine is passed over the object being inspected. The transducer is typically separated from the test object by a couplant (such as oil) or by water, as in immersion testing. There are two methods of receiving the ultrasound waveform: reflection and attenuation. In reflection (or pulse-echo) mode, the transducer performs both the sending and the receiving of the pulsed waves as the "sound" is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an imperfection within the object.

The diagnostic machine displays these results in the form of a signal with an amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection.

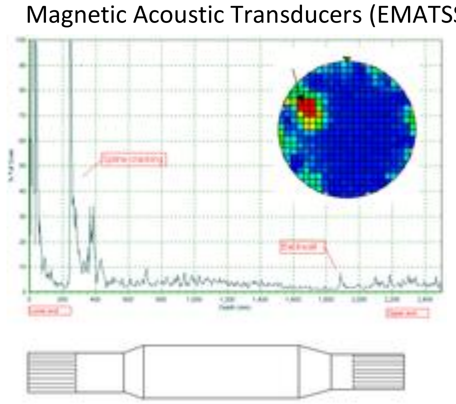
In attenuation (or through-transmission) mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after traveling through the medium. Imperfections or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence. Use ofcouplant increases the efficiency of the process by reducing the losses in the ultrasonic wave energy due to separation between the surfaces.

ADVANTAGES

- High sensitivity, permitting the detection of extremely small flaws.
- Only one surface needs to be accessible.
- Greater accuracy than other non-destructive methods in determining the depth of internal flaws and the thickness of parts with parallel surfaces.
- High penetrating power, which allows the detection of flaws deep in the part.
- Some capability of estimating the size, orientation, shape and nature of defects.
- Non-hazardous to operations or to nearby personnel and has no effect on equipment and materials in the vicinity.
- Capable of portable or highly automated operation.

DISADVANTAGES

- Extensive technical knowledge is required for the development of inspection procedures.
- Parts that are rough, irregular in shape, very small or thin, or not homogeneous are difficult to inspect.
- Surface must be prepared by cleaning and removing loose scale, paint, etc., although paint that is properly bonded to a surface need not be removed.
- Manual operation requires careful attention by experienced technicians
- Inspected items must be water resistant, when using water based couplants that do not contain rust inhibitors.
- Couplants are needed to provide effective transfer of ultrasonic wave energy between transducers and parts being inspected unless a non-contact technique is used. Non-contact techniques include Laser and Electro Magnetic Acoustic Transducers (EMATSS).



Sample Image [3]

PROPOSED MODIFICATION

- Manual Ultrasonic testing is carried out by humans which requires huge skills and perfect positioning of probe in order to get perfect results. As, manual operation is involved there are a lot of errors.

- Instead of manual testing, place the Ultrasonic crack detection system above the axles at the base of wagon which will continuously monitor the axles, wheels for surface and internal cracks.
- The obtained results will be transmitted from the sensors to the computer located at the engine through wireless communication.
- The computer will analyse the results and compare it with the preloaded safe parameters.
- If the system detects any flaws, cracks within the axle, shafts, wheels, it will analyse the degree of crack and damage.
- After analysing it will give a warning to the loco pilot that there is a possibility of failure and will send an SOS signal to the control station.
- The driver and the control station after receiving the warning can take necessary actions in order to prevent any damage and accident.

Result Analysis

The design process regarding the placement of Ultrasonic crack detection system is under process. The communication process and the programming of the computer that will analyse the signal is still under process and analysis.

CONCLUSION

- After analyzing the above cases, it is found that implementing the suggested technique will have various advantages over the initial disadvantages stated using the conventional locos and carriages.
- Designing and manufacturing considering the methodologies suggested will result in less manufacturing cost, more efficiency and will reduce the carbon foot print by a huge margin.
- The above aspects are just a theoretical imagination and can be implemented after some research and experimentation.
- The calculations performed in this paper are based on basic equations neglecting many additional effects.
- Detailed calculations can be done after initial practical implementation.
- So, the entire motive of this paper is to clear out the line congestion caused by slow moving goods train along with proper utilization of energy by Indian Railways.

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