Fire Safety Mechanism in Railway Trains

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Abstract— In recent times there have been accidents involving trains where fire broke out in railway coaches causing death or severe burns to passengers. This is basically due to the lack of safety features in the train and ill-preparedness of the general public. Through this project we plan to provide a fire safety mechanism so as to overcome fire disasters in trains. We plan to introduce a fire safety mechanism that would if not prevent a fire, at least cut it out before it can spread. In this project we plan to install fire sprinklers and sensors on the ceiling of railway coupes. We have arranged an array of sprinklers and sensors in a prototype that is meant to represent the interior of a railway train coach. We are using a fire sprinkler to detect and start off the process of firefighting. A fire sprinkler is a device that consists of a nozzle that is blocked by a glass bulb containing liquid. This device is connected to a source of water. As smoke rises and heats the bulb, the liquid expands and breaks the glass bulb. This opens the flow of water and douses the fire.

Key words: Fire, fire sprinkler, fire sensor, fire safety

I. INTRODUCTION

A. FIRE

Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products (National Wildfire Coordinating Group, 2009). Slower oxidative processes like rusting or digestion are not included by this definition.

Fire is hot because conversion of the weak double bond in molecular oxygen, O2, to the stronger bonds in the combustion products carbon dioxide and water releases energy (418 kJ per 32 g of O2); the bond energies of the fuel play only a minor role here (Schmidt-Rohr, 2015). At a certain point in the combustion reaction, called the ignition point, flames are produced. The flame is the visible portion of the fire. Flames consist primarily of carbon dioxide, water vapor, oxygen and nitrogen. If hot enough, the gases may become ionized to produce plasma. (Helmenstine, 2009).

B. FUEL

Any combustible substance which will burn when heated to its ignition temperature is known as fuel.

The importance of the spread of fire to all firefighting operations cannot be over emphasized. Fire grows as fast as they can develop a fire temperature in the surrounding material. Before a fire is successfully extinguished, its class must be identified so that the proper extinguisher will be used.

C. HEAT

There are three stages of temperature relative to ignition of a material namely: Flash Point, fire point and ignition temperature.

1) Flash Point – is the temperature of the substance at which it will give a vapor sufficient to form an ignitable mixture.
2) Fire Point – is the lowest temperature at which vapors being given off-by a material can be ignited and will continue to burn.
3) Ignition Temperature – is the temperature at which the vapor being given off-by substance will ignite spontaneously in the air.

D. Prevention Strategy

An effective fire prevention strategy is a significantly important feature of fire protection. However, it must be kept in mind that regardless of the efficiency of a fire prevention strategy, some fires inevitably occur.

There exists large number of different types of firefighting equipment and suppression systems like CO2, FM 200, and NOVEC, to suit specific requirements. Automatic fire sprinklers in combination with detection are the most effective fire protection system found in High Rise buildings which can, not only detect the fires, but also extinguish the fires in the initial stage itself. Application of Water Mist in various situations is gaining momentum every day. Passive fire protection system is also becoming more and more popular in India.

It is estimated that a fire discovered within two or three minutes of its outbreak may be extinguished with less than 1000 liters of water. if the water, however is not applied until 5 to 10 minutes later, which is probably the shortest time in which a fire brigade may reach the scene of the fire, the fire will have grown to such proportions that between 50 to 100 times as much water may be needed for extinguishing the fire, making it intensely difficult to douse the fire.

E. Causes of Fire in Trains

The following are the causes of fire in Trains:

1) Carrying stoves, gas cylinders, kerosene oil, petrol, fireworks etc. in passenger compartments.
2) Making fire/using fire near paper, wood, petrol or such other inflammable articles.
3) Lighted match sticks, cigarette ends carelessly thrown.
4) Short circuit in electrical wirings.
5) Using naked light during authority token delivery to the driver, shunting of inflammable loads, sealing of inflammable wagons.
6) Use of open fire, smoking near gas/ petrol tank.

F. Automatic Alarm System

which alerts all the passengers at sleep during night Thereby the people can put maximum effort to safe guard themselves as well to control the fire.

G. Zigbee Wireless Sensor Network

which transmits signal to the engine driver panel enabling the warning light and alarm to function. The Engine driver stops the train. The main reason for stopping the engine is to avoid spreading of fire to other compartments when train is moving into the wind. Simultaneously the driver informs to the concern authority for help.

H. Automatic Water Sprinkler System

which is energized and shut-off valve opens. It allows water to enter into the sprinklers and get sprayed. Now the temperature and the heat intensity are reduced. These three processes are mainly used for controlling the fire accidents on running train.

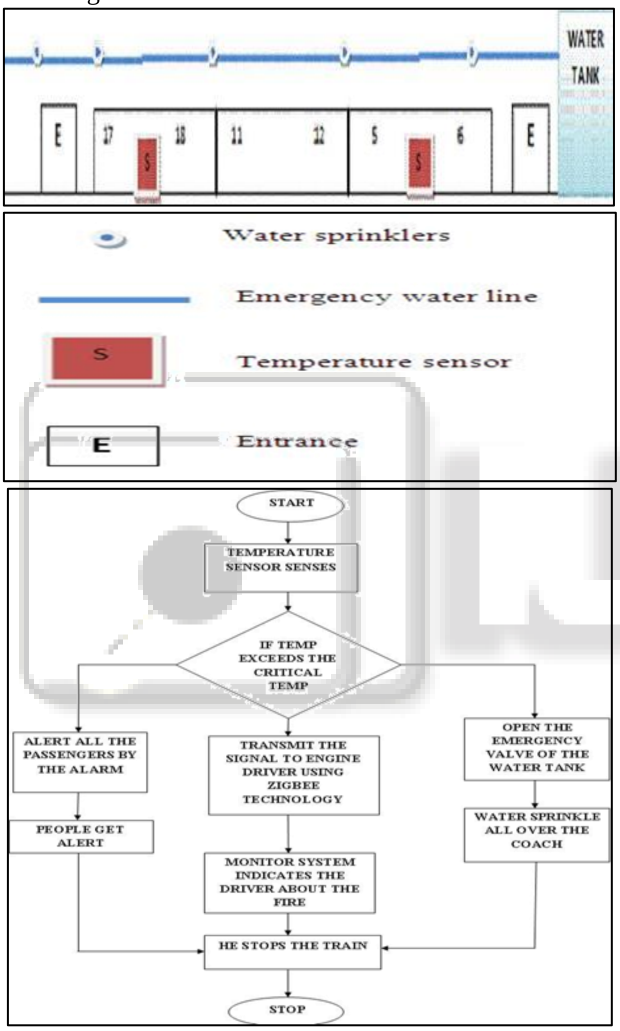

Fig. 1: Flow chart of working of zigbee wireless sensor network

Wireless sensor network are increasingly applied in the field of fire safety and monitoring, especially in difficult and harsh workstations such as mines, ships, submarines. In addition, wireless sensor technology has a broad application background in the field of real time forest fire monitoring. This system has not been applied in practical train fire monitoring. To monitor temperature and humidity in the coach in a more timely and precise way, we pointed out unique advantage of safety in signal transmission, flexibility in network set up and low cost. We propose this system as a first attempt and compliment to Indian railways fire monitoring system. To extend the potential of the system and improve the Indian railways to implement on priority basis in order to avoid train fire accidents in future.

Fire especially in uncontrolled state is a source of very rapid destruction and this gets compounded when loss of human life is involved. Hence, taking all possible steps to prevent a fire from breaking out in coaches, and if it breaks out, to prevent it from spreading and causing further damage is being given great importance.

Fig. 2: Fire accident in train
Source:(https://i.ytimg.com/vi/1pRkiaA8D0I/hqdefault.jpg)

The following points summarize the characteristics of a train fire, which need special consideration when deciding upon counter measures: -

1) A train consists of long narrow vehicles with limited exits coupled with each other.
2) High traveling speeds prevent quick escape and assist the rapid spread of fire.
3) Wide range of track conditions, including confined sections such as bridges, tunnels, Ghats, etc., make it difficult for passengers to get off the vehicle easily in times of emergency.
4) Restriction in movement of passengers and fast spread of fire aggravates the situation.
5) A large number of passengers traveling on trains are attended to by a small team of train crew.
6) Even a delay of few initial seconds due to inadequacy of direct communication with the crew can be devastating.
7) Even smoke emission in a confined place may lead to panic.

II. STATISTICS OF FIRE RELATED ACCIDENTS

A. Fire and Other Accidents

Fire on a running train is more catastrophic than on a stationary one, since fanning by winds helps spread the fire to other coaches. Moreover, passenger's sometime jump out of a running train on fire resulting in increased casualties.
A fire can happen at any time at any place irrespective of its occupancy status. You can expect a fire at any structure, may be at your home or at your workplace or in a hospital or in public places like theatres, malls, etc… Fire in any occupancy has the potential to cause harm to its occupants and severe damage to property.

B. J. Action to Be Taken In Case Of Fire in Train:

The following guidelines have been taken from the

1) First and foremost immediately summon the fire brigade.
2) Secondly, if you smell gas or vapor, or even in case of excessive smoke, hold a wet cloth loosely over your nose & mouth and breath through it in as normal a manner as possible.

III. FIRE SPRINKLER

A fire sprinkler or sprinkler head is the component of a fire sprinkler system. Water is discharged when the effects of a fire have been detected, such as when a predetermined temperature has been exceeded. Fire sprinklers are extensively used worldwide, with over 40 million sprinkler heads fitted each year. In buildings protected by properly designed and maintained fire sprinklers, over 99% of fires were controlled by fire sprinklers alone

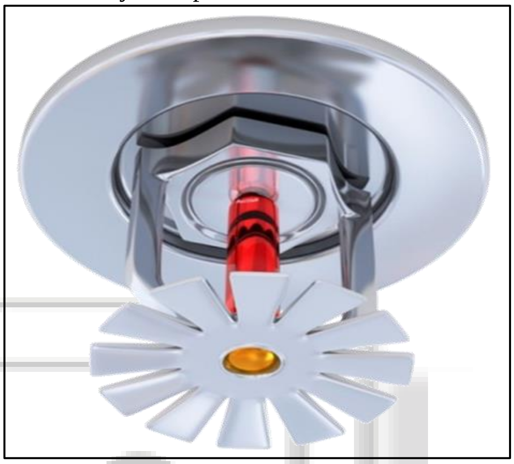

Fig. 3: Fire Sprinkler

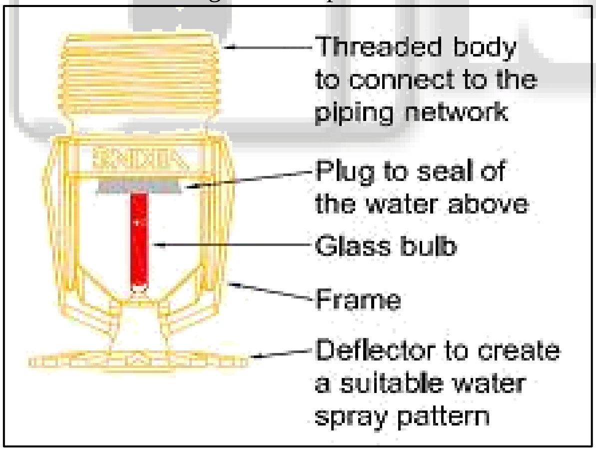

Fig. 4: Fire sprinkler descriptive

Max. Ceiling Temperature	Temperature Rating	Temperature Classification	Liquid Alcohol Glass Bulb Colour
100°F / 38°C	135-170°F / 57-77°C	Ordinary	Orange 135°F) or Red (155°F)
150°F / 66°C	175-225°F / 79-107°C	Intermediate	Yellow 175°F or Green293°F
225°F/107°	250-	High	Blue
C	300°F/121-149°C		

Table 1: Fire Sprinkler Color Codes

Fig. 5: Piping with Sprinkler

A. *Sprinkler Operation*

Fig. 6: A sprinkler with a green bulb indicating a liquid alcohol

Each closed-head sprinkler is held together by either a heat-sensitive glass bulb or a two-part metal link held together with fusible alloy such as metal and other alloys with similar compositions. The glass bulb or link applies pressure to a pipe cap which acts as a plug which prevents water from flowing until the ambient temperature around the sprinkler reaches the design activation temperature of the individual sprinkler. Because each sprinkler activates independently when the predetermined heat level is reached, the number of sprinklers that operate is limited to only those near the fire, thereby maximizing the available water pressure over the point of fire origin.

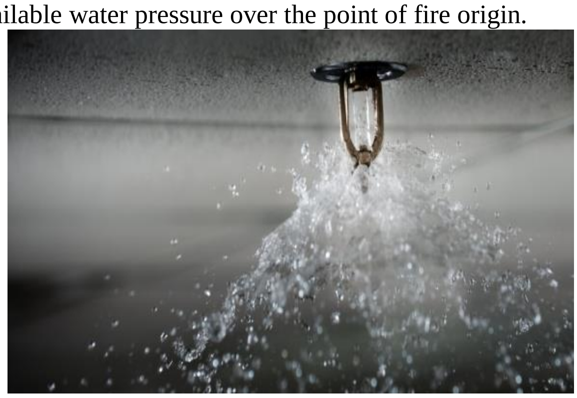

Fig. 7: Opened Sprinkler

The bulb breaks as a result of the thermal expansion of the liquid inside the bulb. The time it takes before a bulb breaks is dependent on the temperature. Below the design temperature, it does not break, and above the design temperature it breaks, taking less time to break as temperature increases above the design threshold. The response time is expressed as a response time index (RTI), which typically has values between 35 and 250 $m^{½}s^{½}$, where a low value indicates a fast response. Under standard testing procedures (135 °C air at a velocity of 2.5 m/s), a 68 °C sprinkler bulb will break within 7 to 33 seconds, depending on the Tithe RTI can also be specified in imperial units, where 1 $ft^{½}s^{½}$ is equivalent to 0.55 $m^{½}s^{½}$.

IV. ELECTRONIC CIRCUIT

In this project we have used a circuit involving a thermal sensor, a wireless transmitter and receiver, and a microprocessor.

A. L. Thermal Sensor- LM 35

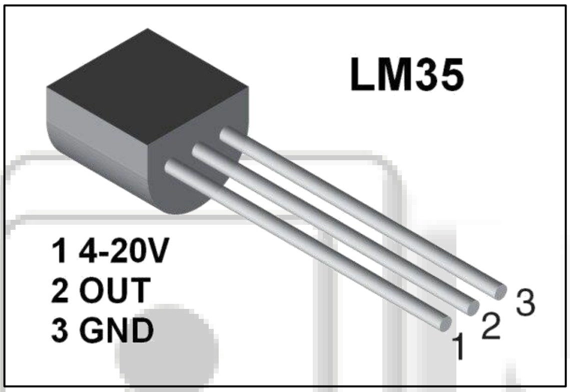

Fig. 8: LM 35 Thermal sensor

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy.

B. M. Microprocessor- ATmega8

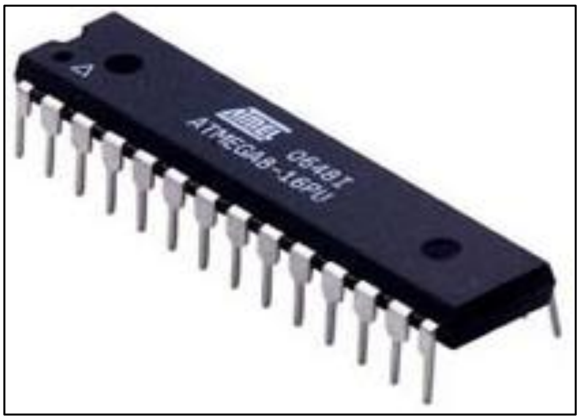

Fig. 9: Microprocessor- ATmega8

A microcontroller is a small computer (SoC) on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications consisting of various discrete chips

C. N. Wireless transmitter and receiver- RF module

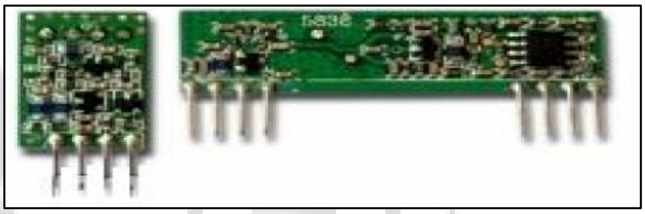

Fig. 10: RF Module

RF module (radio frequency module) is a (usually) small electronic device used to transmit and/or receive radio signals between two devices. In an embedded system it is often required to communicate with another device wirelessly. This wireless communication may be accomplished through optical communication or through radio frequency (RF) communication. For many applications the medium of choice is RF since it does not require line of sight. RF communications incorporate a transmitter and/or receiver.

D. O. Transmitter modules

An RF transmitter module is a small PCB sub-assembly capable of transmitting a radio wave and modulating that wave to carry data. Transmitter modules are usually implemented alongside a micro controller which will provide data to the module which can be transmitted. RF transmitters are usually subject to regulatory requirements which dictate the maximum allowable transmitter power output, harmonics, and band edge requirements.

E. P. Receiver modules

An RF receiver module receives the modulated RF signal, and demodulates it. There are two types of RF receiver modules: super heterodyne receivers and super-regenerative receivers. Super-regenerative modules are usually low cost and low power designs using a series of amplifiers to extract modulated data from a carrier wave. Super-regenerative modules are generally imprecise as their frequency of operation varies considerably with temperature and power supply voltage. Super heterodyne receivers have a performance advantage over super-regenerative; they offer increased accuracy and stability over a large voltage and temperature range. This stability comes from a fixed crystal design which subsequently leads to a comparatively more expensive product.

F. Q. Alarm system

Fig. 11: Fire Alarm

V. PROTOTYPE OF PROPOSED PLAN

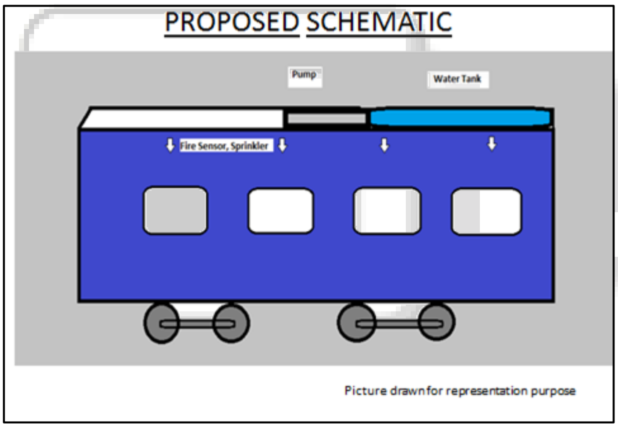

Fig. 12: Proposed Schematic

As per the figure shown above, we plan to install fire sprinklers and sensors on the ceiling of railway coupes.

The water tank provided for washroom purposes at the vestibule is to be fitted with an additional 100 liters capacity.

Here a connection to the main tank and to the rest of the tanks in the train is to be made by a 3/4th inch dia pipe. This is to ensure maximum availability of water at the site of fire.

Fig. 13: Frame

A. R. Piping.

We have used 3/4th inch diameter water pipes connected to a syntax loft tank of 100 liters capacity at one side and the fire sprinkler circuit (with 2 fire sprinklers) on the other

Fig. 14: Water tank and Piping

B. S. Sprinkler

We have used a red alcohol glass bulb sprinkler. It has a temperature classification as 'ordinary'. This sprinkler sets off at 68^{O}C.

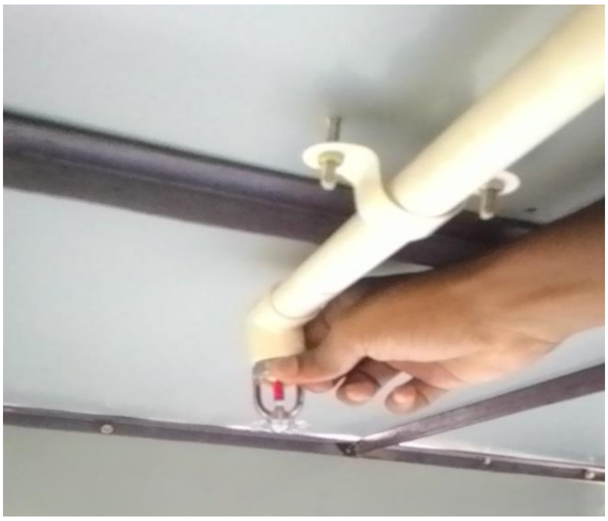

Fig. 15: Sprinkler attached at an end opening of water pipe.

C. T. Working

In this project, we have arranged an array of sprinklers and sensors in a prototype that is meant to represent the interior of a railway train coach. A water tank is installed above the frame and is connected to the underside of the frame by a 3/4th inch diameter plastic pipe.

The frame is made of right angled rods as the outer boundary of a train coach. We have used a 0.5mm thick MS sheet as the body cover and to act as the walls as well.

In the event of a fire, the mechanical fire sprinkler is required to reach 68^{O}C to go off.

The hot air raises the temperature of the red alcohol within the sprinkler bulb and causes volumetric expansion. This causes the fracture of the bulb it is placed in, leading to the flow of water from the water supply.

We have arranged electrical sensors that get setoff at 70^{O}C. It sends a signal to the driver's cabin that shows the exact location of the fire so that maximum attention can be directed to that bogie.

Also, to prevent the possibility of situational unawareness, there is a provision for a fire alarm in every coach. This is actuated by a wireless transmitter which is fixed to the sensor

VI. Calculation

Terminology used in the calculation of performance of train post the addition of water tank.

A. U. Drag Force

In fluid dynamics, drag (sometimes called air resistance, a type of friction, or fluid resistance, another type of friction or fluid friction) is a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid (Merriam- Webster dictionary). This can exist between two fluid layers (or surfaces) or a fluid and a solid surface. Unlike other resistive forces, such as dry friction, which are nearly independent of velocity, drag forces depend on velocity. Drag force is proportional to the velocity for a laminar flow and the squared velocity for a turbulent flow. Even though the ultimate cause of a drag is viscous friction, the turbulent drag is independent of .

Drag forces always decrease fluid velocity relative to the solid object in the fluid's path.

A drag force is the resistance force caused by the motion of a body through a fluid, such as water or air. A drag force acts opposite to the direction of the oncoming flow velocity. This is the relative velocity between the body and the fluid.

The drag force D exerted on a body traveling through a fluid is given by

$$F_d = C_d A \rho \frac{V^2}{2}$$

where: C is the drag coefficient, which can vary along with the speed of the body. But typical values range from 0.4 to 1.0 for different fluids (such as air and water) ρ is the density of the fluid through which the body is moving v is the speed of the body relative to the fluid A is the projected cross-sectional area of the body perpendicular to the flow direction (that is, perpendicular to v).

B. V. Rolling resistance

Rolling resistance, sometimes called rolling friction or rolling drag, is the force resisting the motion when a body (such as a ball, tire, or wheel) rolls on a surface. It is mainly caused by non-elastic effects; that is, not all the energy needed for deformation (or movement) of the wheel, roadbed, etc. is recovered when the pressure is removed. Two forms of this are hysteresis losses (see below), and permanent (plastic) deformation of the object or the surface (e.g. soil). Another cause of rolling resistance lies in the slippage between the wheel and the surface, which dissipates energy. Note that only the last of these effects involves friction, therefore the name "rolling friction" is to an extent a misnomer.

The coefficient of rolling resistance for a slow rigid wheel on a perfectly elastic surface, not adjusted for velocity, can be calculated by (Hibbeler, R.C., 2007)

$$C_{rr} = \sqrt{z/d}$$

Where

z Is the sinkage depth

d Is the diameter of the rigid wheel

C. W. Co-efficient of friction

The friction force is the force exerted by a surface when an object moves across it - or makes an effort to move across it. The frictional force can be expressed as

$F_f = \mu N$ (1)

Where

F_f = frictional force (N, lb)

μ = static (μ_s) or kinetic (μ_k) frictional coefficient

N = normal force (N, lb)

There are at least two types of friction forces

- kinetic (sliding) friction force- when an object moves
- static friction force - when an object makes an effort to move

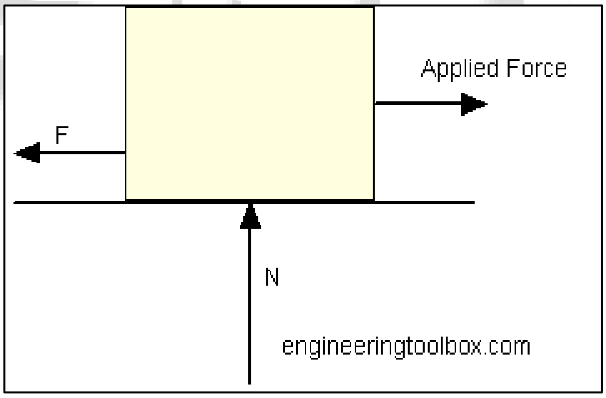

Fig. 16:

VII. Weight consideration

For a 20 bogie general Intercity let's assume the following configuration:

The rake contains one AC Chair Car, 2 Parcel Vans and 17 General Coaches hauled by a Diesel Locomotive.

Diesel Locomotive: WDM-3A Weight: 112.8 tones

Chair Car (empty): 43 tones (loaded): 47 tones

Parcel Van (empty): 38 tones (loaded): 54 tones

General bogie: 37 tones loaded: 49 tones

Total weight unloaded: 860tonnes

Loaded: 1084tones

Thus a general Indian train would roughly weight around 1100 tones.

Source:https://www.quora.com/How-much-would-a-general-Indian-Train-weigh

A. *Scenario I: addition of 200 liters /bogie*

Consider the addition of 200 liters on the 20 bogies of a train. The total weight of the water, (200litres in 20 bogies) adds up to 4000litres, i.e. 4 tones. Considering the total weight of the train being 1084 tones, when the there is an addition of 200 liters on all 20 bogies, the weight of the train adds up to 1088 tones. (Weight of train+ weight of additional water on 20 bogies). Thus weight of train now equals 1088 tones (1084+4)

B. *Scenario II: addition of 300 liters /bogie*

Consider the addition of 300 liters on the 20 bogies of a train. The total weight of the water, (300 liters in 20 bogies) adsup to 6000litres, i.e. 6 tones. Considering the total weight of the train being 1084 tons, when the there is an addition of 300 liters on all 20 bogies, the weight of the train adds up to 1090 tons. (Weight of train+ weight of additional water on 20 bogies). Thus weight of train now equals 1090 tons (1084+6).

C. *Y. Load on Engine*

Condition I: Force required moving train
Total force required to move a train $T_f = F_d + F_{rr} + F_i$.
Here drag force $F_d = ½ \times C_d \times A \times V$
$½ \times 1.05 \times (304.8x121.92) \times (0.092)^2 = 165.129$ N
F_i = Acceleration ×Weight
Acceleration= maximum velocity ÷ time required to reach it
Acc. = 27.7 ÷ 300 = 0.092
Thus, $F_i = 0.092 \times 1100000 = 101200$ N
$F_{rr} = C_r \times W \times g$
$F_{rr} = 0.0010 \times 1100000 \times 9.81 = 10791$ N
Thus total Force = 165.129 + 101200+ 10791 = 112156.129 N or 112.15 KN
Condition II: force required to move train with additional weight (4 tons)
Total force required to move a train $T_f = F_d + F_{rr} + F_i$.
Here drag force $F_d = ½ \times C_d \times A \times V$
$½ \times 1.05 \times (304.8x121.92) \times (0.092)^2 = 165.129$ N
F_i = Acceleration ×Weight
Acceleration= maximum velocity ÷ time required to reach it
Acc. = 27.7 ÷ 300 = 0.092
Thus, $F_i = 0.092 \times 1104000 = 101568$ N
$F_{rr} = C_r \times W \times g$
$F_{rr} = 0.0010 \times 1104000 \times 9.81 = 10830$ N
Thus total Force = 165.129 + 101568 + 10830 = 112563 N or 112.56 KN
Thus the difference between force required in conditions I and II is410 N (112.56 KN – 112.15 KN)

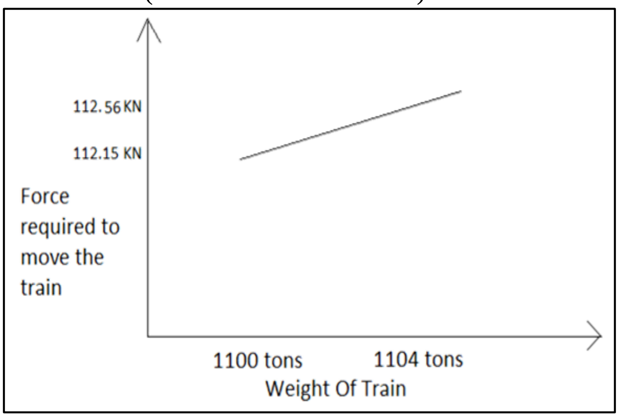

Fig. 17:

Graph showing the relation between weight of train and the force required to move the train.

VIII. Conclusion

The motivation for us to take up this project was the fact that India possesses one of the largest railway networks in the world and happens to be the most vulnerable to a fire mishap.

There have been many lives lost on account of unavailability of safety mechanisms and also mechanisms to counter a fire hazard. Added to this, there is the general lack of awareness among the common public about how to deal with such eventualities.

Therefore, by establishing a warning system as well as a fire fighting system, we hope to cut out the possibility of fire causing havoc on trains. Though a fire may not completely be averted, if there were a case of fire breaking out, our mechanism would be in place to cut it off in its initial stages itself.

IX. Scope of Future Work

What we see as a future extension for this work could be the replacement of water used as a douser, that is, if another compound can be created or discovered that is easier to handle than water and is more potent in putting out a fire then the fire safety mechanism could be made more efficient.

If there is change in fire extinguisher technology that makes the storage of CO_2 easier and cheaper, then fire extinguishers could be used in place of what we have used. There could be developments made such that the extinguishers can sense and operate on their own. This would cut off human intervention, thus making it easier to handle and maintain

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