Flash-Butt welded Long Rolled Rails, LRR, of Prime Steel Quality help to lower the Risk of fatal Train Accidents in India

F.A. Wingler

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Dr. F.A. Wingler
drwingler railroad modelling & consultancy
Doenhoffstr. 92
D 5173 Leverkusen, Germany
Tel.: +49 214 44337
E-mail: drwingler@web.de
Website: http//www.drwingler.com

Flash-Butt welded Long Rolled Rails, LRR, of Prime Steel Quality help to lower the Risk of fatal Train Accidents in India

By F.A. Wingler, January 2021

Laying new Track with Long Rolled Rails, LRR; pict.: Aloy Rumania

SYNOPSIS:

Long Rolled Rails, LRR, of prime steel quality, already tested in the manufacturing plant, and with Flash-Butt Welds of higher strength than that of Alumino Thermic, AT, welds, provide far better alignment and continuity parameters with less alignment perturbations for far smoother train runs with less dynamic response of rail vehicles, that lower the risk of in-service rail failures, which had led in past decades to nasty,

unwanted and fatal train derailment accidents. The mutual impacts of rail and running wheel governed by Newton`s Laws of Motion (= dynamic response) are on tracks consisting of flash-butt welded long rolled rail panels far lower than on tracks consisting of AT welded short 13 m rails.

The recent Indian evolution of indigenous manufacture of **Flash-Butt Welded Long Rolled Rails** of prime Steel Quality is a **MAJOR ACHIEVEMENT** for INR of the last decade on the way to avoid nasty, unwanted and fatal train accidents and to extend the service life of rails in track and that of the other track components resulting in lower overall Life Cycle Costs.

Long rolled and flash-butt welded rails are a prerequisite for 160 kmph Semi-High Speed Lines in India.

CORRELATION BETWEEN FATAL TRAIN ACCIDENTS AND RAIL TRACKS CONSISTING OF AT WELDED SHORT 13 m RAIL PANELS:

There is no other country around the globe than India, from where in the last decades so many nasty and unwanted fatal train accidents could be reported; see contributions in http://www.drwingler.com.

Mahakaushal Express Derailment near Kulpahar, 30.03.2017

In India, one thought, one could not keep rails longer than 13 m, otherwise the expansion gaps at the joints, hold together in position by bolted fish-plates, might become too wide; see J.S. Mundrey, Railway Track Engineering, 5th print edition, 2017, page 49, 103 ff and 329, McGraw Hill Education (India) Private Limited, Chennai, ISBN (13): 978-93-5260-648-1 / ISBN (10): 93 -5260-648-5. It had been considered that the gap between the rail ends should be proportional to the length of the rails to allow free expansion during hot weather.

The gaps between rail ends were generally thought to be the prime cause of impact at joints. Although the provision of longer rails would lead to a reduced number of joints, it was dis-favoured in India due to the increase of impact-density, if proportionately wider gaps were to be provided at the ends.

To weld rails in long lengths was therefore technically disinteresting. It was realized later that the intensity of impact is not directly proportional to the width of the gap, and the gap itself must not be exactly proportional to the length of the rail because the rail does not really behave as a free rail when laid in track. With this realization any reduction in the number of joints was welcome, as it had the prospect to minimize, if not completely eliminate, the problems connected with the jointed track.

With this background, the welding of rails into 3 rails, 5 rails and 10 rails was started on Indian Railways. The welded panels have been named ***"Short Welded Rails"*** **(SWR)** as distinct from ***"Long Welded Rails"*** **(LWR)**. The experience with short welded rails has been that joints with panels of length more than 3 rails cause more damage to the track than the proportional advantages derived from the elimination of joints. Welded rails panels longer than 3 rails are therefore no longer in use on the Indian rail tracks.

Rails, welded into long strings of 200 m or more, denominated as **LWR/CWR**, behave differently at the joints and are governed by their own inbuilt system. On LWR/CWR track the expansion and shrinking forces get arrested over the frictions at the rail-seats, the rail-fastenings and sleepers in the track-bed.

With the introduction of concrete sleepers and stronger track-bed structures efforts are made to have continuously welded track to the extent possible, as jointed track on concrete sleepers is beset with many

maintenance problems including the structural failures of concrete sleepers at joints and ballast degradation. Step by step the short 13 m panels, jointed by bolted fishplates, have been Alumino Thermic (AT) welded to LWR/CWR tracks.

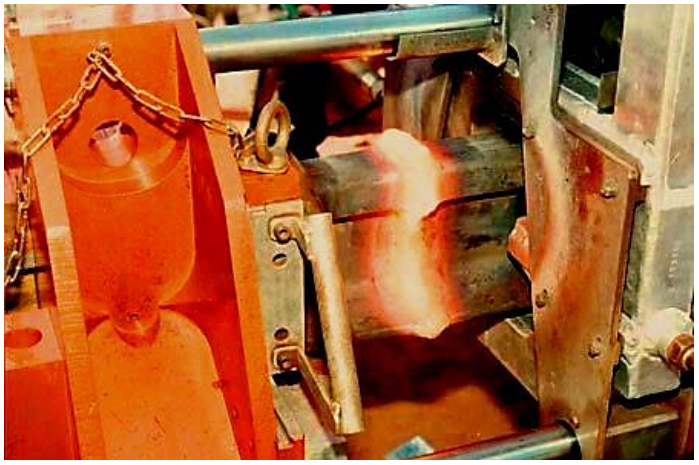
AT Welding on Kashmir Valley Railway Line; source: Northern Railway; India

Modern Digital controlled AT *"SmartWeld"* High Quality Rail-Welding by Th. Goldschmidt`s Digital controlled Process

AT welding is the common conventional welding method, which enables rails to be manually welded in a relatively short time with simple devices at site. However, it is necessary to carefully control its quality at the point of installation, in terms of track component condition, assembly, and the welding procedure itself by well trained work forces.

A good quality AT weld has a **Fatigue Life** of only about 56 % as compared to the parent rail, whereas a Flash-Butt Weld has a Fatigue Life of about 90 %. Japanese Gas Pressure Welds reach a Fatigue Life of 96%, however Gas Pressure Welding needs skilled work-forces and is only best suitable for stationary welding in factory or at site. See M.M. Agarwal, ***INDIAN RAILWAY TRACK***, twentieth edition, 2017, p. 384, Prabha & Co. Delhi, India, ISBN 81-900613-1-3.

Gas Pressure Rail Welding at Site

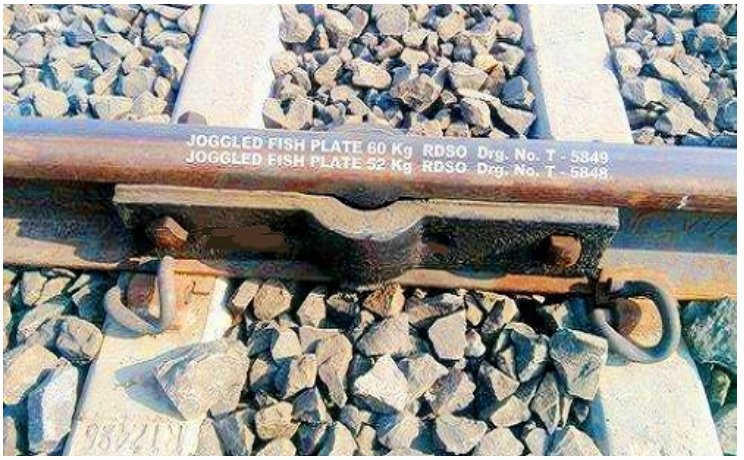


Gas Pressure Weld

Often the AT welds on INR tracks are below standard, and the Fatigue Life is mostly below 56 %. This means, on an Indian LWR/CWR tracks consisting of AT welded 13 m rail panels, there are every 13 m weak spots and discontinuities/disturbances in rail strength and alignment parameters. **With 13 m rails, every 13 m there is a track geometry perturbation.** INR tries to secure those weak spots with **Joggle Fish Plates.**

The numerous Joggle Fish Plates on INR tracks reveal that INR is aware of the Risks of AT Weld Failures. To mitigate the impact of AT Weld Failures, which may lead to nasty fatal railway accidents, INR therefore tries to secure the AT welds with Joggle Fish Plates:

Finishing, Stripping and Grinding of AT Rail Weld



Joggle Fishplate Rail Joint for INR from Chandra Industrial Works to secure AT Welds

Securing Rail Fracture with temporary Joggle Fishplate

In addition, the alignments of the welds are often inferior. On INR, bends in the vertical and horizontal plane of AT welds are tolerated up to 0.7 mm, measured with a 1.5 m straight edge. For flash-butt welds a tolerance of max. 0.3 mm, measured with a 1.0 m straight edge, got stipulated. Poor alignments with discontinuities increase the lateral and vertical dynamic load application and the stress between running wheel/rail-vehicle and rail, governed by the Newton`s Law of Mechanics. The consequence is an increased destruction of all track components:

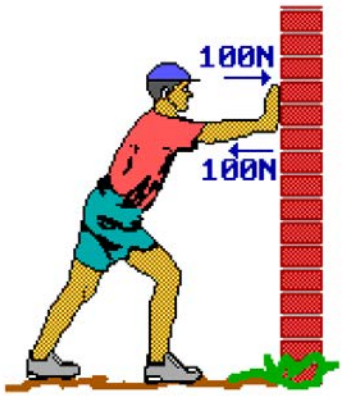
NEWTON`S LAWS OF MECHANICS, THE DYNAMICS OF TRACK-TRAIN INTERACTIONS AND RELATED PROBLEMS:

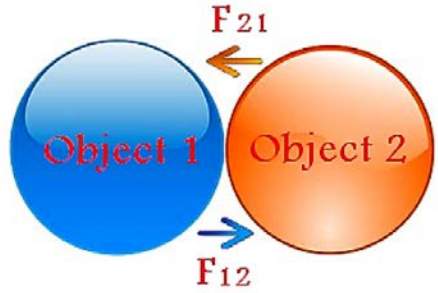
See: A.D. Kerr *FUNDAMENTALS OF RAILWAY TRACK ENGINEERING*, Simmons Boardman Book, USA, ISBN: 0-911 382-40-2, 2003, p. 252.

Newton`s **FIRST LAW** suggests that any change of velocity of a body under consideration must be associated with the counter-action of a resultant force, which acts on this body. This in turn suggests a relationship between the resultant force and the acceleration of the body.

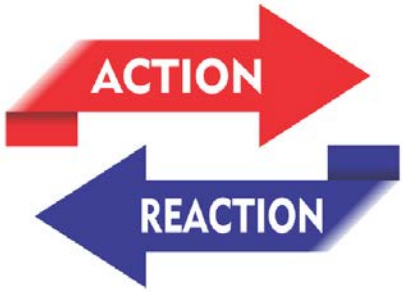
Newton assumed by his **SECOND LAW** the very simple relation that the resultant force, which acts on the body and causes acceleration, is linear related.

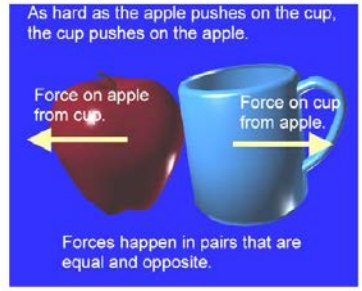
The **THIRD LAW** is the "*LAW OF ACTION AND REACTION"*: “For every **ACTION** there is an equal and opposite **REACTION**”. This is probably the most famous law of motion. This means that if one object 1 acts a force out on another object 2, then object 2 will act the same size force in the opposite direction on object 1; **F21 = F12**. Here are diagrammes to visually show this:





"Action equals opposite Reaction"; F12 equals F21.





To every Action or Force there is an equal and opposite Reaction or Force.

Newton's Laws of Motion

1. Newton's First Law of Motion
   - Every object will continue in a state of rest or with constant speed in a straight line unless acted upon by an external force.

2. Newton's Second Law of Motion

   - When a net force act on an object, the object accelerates in the direction of the net force. The acceleration is directly proportional to the net force and inversely proportional to the mass. Thus, $a \sim F/m$ or, $a \propto F/m$

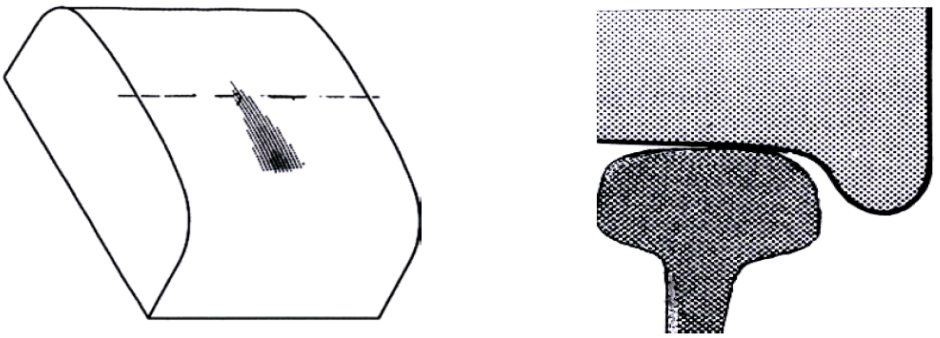
3. Newton's Third Law of Motion
   - Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.

In other words, when a body (rail-track) exerts a force on a second body (rail-vehicle), in consequence the second body (rail-vehicle) exerts a numerically equal but opposite force on the first body (rail-track).

DYNAMIC RESPONSE OF RAIL VEHICLES TO VERTICAL AND LATERAL TRACK GEOMETRY DEVIATIONS:

The force acted on the rail-vehicle causes acceleration in vertical and/or lateral direction and/or causes rotation movements. The extend of the acceleration and rotation is linear related to the force acted by the rail-track on the rail-vehicle and can be used to detect and measure rail-track defects/geometry-perturbations by means of instruments/devices on board of the rail-vehicle (Instrumented Revenue Vehicle; IRV). The "IRV" can be a commercial and scheduled running Locomotive, Passenger Coach or Freight Wagon. See: F.A. Wingler: ***MONITORING INSTRUMENTS MOUNTED ON SCHEDULED RUNNING COMMERCIAL TRAINS (INSTRUMENTED REVENUE VEHICLES, IRV) MAKE USE OF NEWTON`S LAWS OF MECHANICS FOR TRAIN BASED AND IN-SERVICE TRACK-CONDITION MONITORING IN TARGET PLANING OF MAINTENANCE;*** published on: May 18, 2018; http://www.drwingler.com .

The Railway is a system, where steel-wheels run on steel-rails with a non-elastic contact area of less than 3 cm². This means that track and train interact over a contact area of less than 3 cm², and wheels exerting the forces over this small contact area are following Newton`s Laws of Mechanics:



Wheel-on-Rail Contact Area of new Wheel-Tread and Rail-Head Profile on straight Run

When running on a straight rail-track, on a perfect aligned and smooth rail-table without any roughness and with only little rail-deflection under

the wheel load (optimum in the range of 1.5 mm), there are only little additional vertical and lateral inter-acting forces causing acceleration, deceleration and rotation on the rail-vehicle with equal corresponding forces acting on the rails. That is, why a high quality rail-track experience only little additional corresponding dynamic load application forces of the running rail-vehicles acting on the rails. Therefore, a **high quality rail-track** keeps its properties under given traffic load, volume and velocity over a longer period and loses its properties over the time with a slower deterioration rate. The deterioration rate under given traffic load and train speed is an index for track quality.

On **poor quality rail-tracks** of bad alignment and poor bearing capacity with tract defects like, kinks, dips, undulations, twists, high rail-deflections under wheel load (related to deteriorated track components/constituents, poor bearing sub-structure components and poor drainage), rail-table defects and roughness (corrugation, rail-head-burns, RCF), running vehicles experience high additional vertical, lateral and rotation forces exerting equal opposite forces on the rail-track damaging all the track components. With increased speed and accumulation of traffic, the situation can deteriorate rapidly through this mutual ***"SELF-DESTROYING PROCESS".***

Oscillating rail-vehicle movements, self-exited or exited by track alignment defects, like Shuttling, Lurching, Bouncing, Rolling, Pitching, Nosing and Hunting, increase further the deterioration rate of an already deteriorated track.

At **misaligned and un-straight rail-joints and rail-welds** as well by wheels running with flat spots, high impacts are caused. Latter produce high rail and rail-weld bending stress, causing degradation and destruction of rails, rail-welds, rail-fastenings, sleepers, ballast and track sub-structure components.

The geometrically perfect production of welded rail-joints and the correct alignment and rail-surface profiling of the jointed rails are therefore essential parameters for the durability of the welded joints. Rail-straightness and even rail-surfaces of welded joints are decisive factors for the durability of welds. A passenger travelling in a coach on Indian Railway`s tracks can detect nearly each and every rail-weld by the "***tack-tack***" sound, caused by the response of the wheels, when running over un-straight and/or uneven rail-welds. In countries of

advanced railways with perfected welded rail-joints, such sound is not audible.

There is a clear correlation between weld-shape and the dynamic response of the rail-vehicle to the geometry perturbation, which can be monitored by IRV.

In-service rail- and weld failures are in India frequent and have caused many derailment-disasters with high mortality rates:

In-Service Rail- and Weld Failure; Central Railway, near Kalyan (left), near Badlapur (right)

Rail-Weld and Rail-Head Defects leading to fatal and nasty Derailment Disasters on IR

Fatal Kalinka-Utkal Express Derailment near Khatauli on 19th August 2017

Poor quality tracks deteriorate faster, the service life is shorter and more frequent monitoring and maintenance is needed, and in consequence the expenditures or overall life-cycle costs keeping a train service on a poor quality track can be 8-fold higher than on a high quality track.

The Picture Gallery of typical Weld- and Rail-Defects with the **Figures 31 – 56** on page 112 – 125 of the RDSO MANUAL: *ULTRASONIC TESTING OF RAILS AND WELDS*, revised 2012, gives in a terrifying way evidence on what has ailed INR in the past decades causing so many nasty and fatal **RAILWAY ACCIDENTS**.

LONG ROLLED RAILS, LRR, "*MAKE IN INDIA*" – A MILESTONE FOR TRACK IMPROVEMENTS; MANUFACTURE OF LRR:

At present there are two **Rail Rolling Mills** in India. They are:

Bhilai Rail Rolling Mill, SAIL is a public sector plant, which has been producing rails for the last six decades, located at Bhilai in the Indian State of Chhattisgarh. Originally set up with USSR assistance, it has recently been upgraded to roll long rails up to 130 m each. It has

further facilities for welding rolled rails into longer panels in an integrated stationary **Flash-Butt Welding Plant**:

Rail Production at Bhilai Steel Plant, SAIL; India

Bhilai SAIL`s Success Story with Long Rolled R-260 Grade Prime Quality Rails for INR, that found Approval by RDSO

Schlatter stationary Flash-Butt Welding Plant GHA S 80

Stationary Flash-Butt Weld on Long Rolled Bhilai, SAIL, Rail; pict. by F.A. Wingler

The other Rail Rolling Mill has been put up by **Jindal Steel & Power Limited (JSPL**) at Raigarh. This Mill, a relatively new one, was setup in the years 2003-5 and can produce long rails of about 121 m length with the facility to make longer panels up to 480 m in an integrated **Flash-Butt Welding Plant**. Jindal Steel & Power Limited (JSPL) has become

India's first private company to get "Regular Supplier" status from Indian Railways to supply 60 kg 880 grade (90 UTS) Rails.

JSPL produced 1080 HH rails & 880 Grade rails, that have been already approved by RDSO for use by Indian Railways on regular basis. JSPL's 1080 Head Hardened Rails are already being supplied to the Metro Rail Corporations and High-Speed Corridors by JSPL.

JSPL is the first and only Indian manufacturer to successfully develop 60E1 1175 Heat Treated (HT) Rails suitable for High-Speed and High Axle-Load applications. Indian Railways have projected a requirement of 1.8 Lac t per annum of this high-grade 60E1 1175 Heat Treated (HT) Rails.

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Indian Railways has embarked upon upgrading the Indian Railway Track system to carry 25 t axle-load and to allow a speed of up to 200 kmph. Research Designs & Standards Organisation (RDSO) has approved the newly developed 60E1 1175 Heat Treated (HT) Rails of Jindal Steel and Power Limited. 60E1 1175 Heat Treated (HT) Rails are of superior grade to 1080 HH and will be used by Indian Railways for heavier loads and high-speed application; see: M. K. Rai; 20/10/2020; Metro Rail News.

Long Rolled Rails made in India by Jindal Steel

Jindal Steel Rail Rolling Plant

JSPL Steel Manufacture at Raigarh

Both the plants are located in the rich iron ore/coal mining belts of the State of Chhattisgarh, and they are well connected with the rail and road network.

Metro Rail Projects are predominantly designed on **Head Hardened Rails**. Under the Government of India ambitious **"Make in India"** scheme, the two large steel manufacturers took up the initiative to develop **"Head Hardened Rails"** to meet the growing demand of Metro Rail Corporations and High-Speed corridor projects in India.

J.S. Mundrey reports in his article "***India becomes Atmnirbhar* in Head Hardened Rail Production",*** 06/01/2021; Metro Rail News - Daily Round Up from Metro & Rail Industry (*:'self-reliant India'):

Rail making technology in India has undergone a great change. Rails steel is coming now through ***Concast Route*** *with* ***RH Degassing****, completely eliminating the piping in the rails, before a major cause of rail fractures.*

The rail chemistry is nowadays well controlled. The ***Hydrogen Content*** *in the rails produced by Indian Rail Mill is now less than 1.6 ppm, much below the international standards.*

Modern cooling methods and the sophisticated rail straightening machines bring down the ***Residual Stresses*** *to the bare minimum.*

Ultrasonic Testing *of full rails and* ***Eddy Current Testing*** *do not allow any defective rails to pass undetected.*

CAREFUL HANDLING AND TRANSPORT OF LRR:

For the careful handling of long rail panels, special rail transport trains and unloading shutes are deployed. These trains will transport long rolled rail panels to the rail laying sites at a speed of over 80 kmph cutting out zonal flash-butt welding plants from the transport circuit. This will not only save considerable cost but will also reduce damage, presently occurring in handling and transport of rails:

Rail Trailer with long rolled stationary Flash-Butt welded Bhilai, SAIL, Rail Panels (Londa, India); pict. by F. Wingler

Transport of Long Rolled Rails in Canada

Robel Long Rail Transport Trailer, up to 500 m length

Robel *"Spaghetti"* Trailer for Long Rails

Unloading with Robel 40.30 Rail Putler Shute; pict. by DVV Media Group

RAUN Rail Unloading Train with Rail Shute; USA

Picking-up of Long Rolled 60 kg Rails, LRR, for Dedicated Freight Corridor, DFC, with synchronised Cranes; India

LRR ON DEDICATED FREIGHT CORRIDOR, DFC, AND ON SEMI-HIGH SPEED LINES:

For the new Indian Heavy Haul DFC Continuous Welded Rail Tracks (CWR), designed for 32.5 t axle-load, long rolled UIC 60 and 90 kg UTS rails and 60 kg/m HH (Head Hardened) rails on curves of less than 2 degrees (875 m radius) have been introduced.

Ongoing Construction Works on India's Eastern Dedicated Freight Corridor with LRR-CWR Track; photo: Joe Qian/World Bank

Mobile Flash-Butt Welding on Dedicated Freight Corridor with Holland RRV Mobile Flash Butt Welding Machine; Image: DFCCIL

Mobile Flash-Butt Welding on Kashmir Valley Railway Line with Holland, USA, Flash-Butt Welding Unit;
source: Northern Railway; India

Long rolled and flash-butt welded rails are a prerequisite for 160 kmph Semi-High Speed Lines in India; see F.A. Wingler ***SEMI-HIGH SPEED (SHS) ON CURRENT INDIAN RAIL-TRACKS WITH CURRENT INFRASTRUCTURE – WILL IT BE SAFE?*** Published on February 24th, 2019 on http://www.drwingler.com .

CHALLENGE TO IMPROVE EXISTING RAIL TRACKS CONSISTING OF SHORT 13 m AT WELDED WITH LRR RAILS OF PRIME STEEL QUALITY:

The challenge is to replace on old lines all rails consisting of short 13 m rails of insufficient rail steel quality and poor quality AT welds, which are in need of joggle fish-plates, by **Flash-Butt welded long rolled rail panels of prime steel quality**. Another challenge is the proactive and corrective **Rail Management Strategy** under a comprehensive **Friction Management** with ultra sound testing and frequent rail grinding and milling, to prevent surface cracks to penetrate into the rail head leading to rail fractures.

RESUMEE:

Long Rolled Rails, LRR, of prime steel quality, already tested in the manufacturing plant, and with Flash-Butt Welds of higher strength than that of Alumino Thermic, AT, welds, provide far better alignment and continuity parameters with less alignment perturbations for far smoother train runs with less dynamic response of rail vehicles, that lower the risk of in-service rail failures, which had led in past decades to nasty, unwanted and fatal train derailment accidents. The mutual impacts of rail and running wheel governed by Newton`s Laws of Motion (= dynamic response) are on tracks consisting of flash-butt welded long rolled rail panels far lower than on tracks consisting of AT welded short 13 m rails.

The recent Indian evolution of indigenous manufacture of **Flash-Butt Welded Long Rolled Rails** of prime Steel Quality is a **MAJOR ACHIEVEMENT** for INR of the last decade on the way to avoid nasty, unwanted and fatal train accidents and to extend the service life of rails in track and that of the other track components resulting in lower overall Life Cycle Costs.

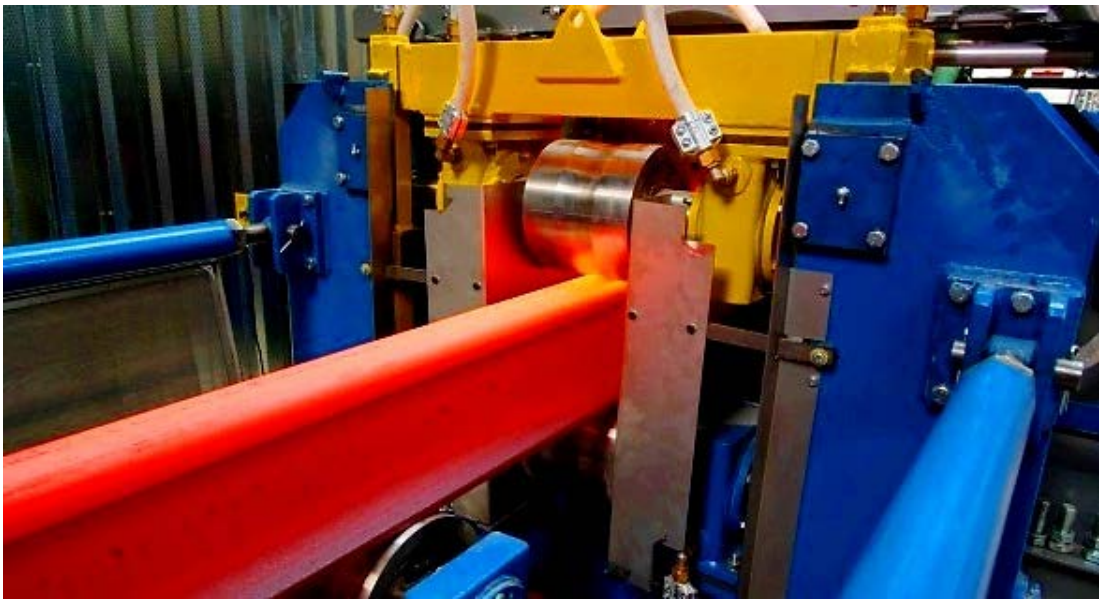
Long rolled and flash-butt welded rails are a prerequisite for 160 kmph Semi-High Speed Lines in India.

Better knowledge about rails in INR will help for better information based planning, actions and decisions at the right place and at the right time in order to bring down the frequency and prevalence of in-service **Failures of Rails and Rail Welds,** one of the root courses of so many unwanted, nasty and fatal train accidents in India.

Fatal Seemanchal Express Derailment due to a Rail Fracture in Vaishall District, Bihar, 03-02-2019

Picture Gallery

Synchronised Picking-Up of Long Rolled Rails, LRR, at Jindal Rail Manufacture Plant: source: JSPL



Rolling of Rail; British Steel

Continuous Welded Rail Track, CWR, with Long Rolled Rails, LRR; USA