Fastclip – Test and experiences on Norwegian State Railways
by Stein Lundgreen, Senior Engineer, Development and Quality Control of Permanent Way, Norwegian State Railways (NSB)

In November 1992, while evaluating alternative fastenings for its new 60 UIC concrete sleeper, NSB installed 500 sleepers in a 400 metre radius curve fitted with a new rail fastening designed by Pandrol, called ‘FASTCLIP’. NSB sees substantial benefits in a fastening without threaded connections which can also be pre-assembled in the concrete sleeper factory. These benefits include manpower savings, stockkeeping, distribution and handling, particularly during tracklaying, de-stressing and rail changing.

De-stressing of the test length in May 1993 verified the rapid unclipping and re-clipping capability claimed by the supplier.

After approximately 1 year in track, and 9 million gross tonnes of traffic, the track geometry car produced a perfect recording. In particular the gauge diagram was most impressive.

NSB will evaluate its experience with FASTCLIP in the near future in deciding whether to adopt it as standard on our lines.

At the beginning of November 1992, NSB installed about 500 pre-stressed microblock concrete sleepers with Pandrol’s new FASTCLIP rail fastening. The 2.4 metre sleepers were produced by our concrete sleeper manufacturer Otsprem and the fastening components were supplied by Pandrol to be pre-assembled on the sleepers at the sleeper factory. The sleepers were dispatched to the relay site complete on the sleeper wagons associated with our Plasler SMD 80 track relay machine.

The test site chosen was a 400m rail curve on one of our double tracked main lines in the vicinity of Oslo, carrying 115 trains daily on each track. Maximum speed and axle load are 90 km/h and 22.5 tonnes respectively. Cant deficiency is 90mm and the gradient 1.6%.

The purpose of the test was to gain experience with this new fastening, as NSB was considering which fastening to apply to the new concrete sleeper recently designed for UIC 60 rail.

Several of the rail fastenings on the market were evaluated but Pandrol’s FASTCLIP concept was regarded as the most interesting. The advantages of using a fastening without threaded connections, which in addition can be fully pre-assembled in the sleeper factory, were felt to be considerable and in the future NSB envisage substantial benefits in stockkeeping, logistics and handling.

NSB foresee track relay taking place with modern renewal equipment, removing old components, followed by sleeper and rail replacement and finally clipping up of the rail fastenings, all of this carried out in one fluent operation using a minimum of manpower.

NSB’s rail network contains long sections where crossbars are numerous, making effortless rail changing and de-stressing of the utmost importance. Here the benefits of FASTCLIP become particularly apparent in that the fastening may be released in a single movement and the clip toe load regained by moving the clip back to position with further single movement using a simple and inexpensive machine. This would reduce the track laying team by 4-5 men.

By October 1993 the FASTCLIP test section had been subjected to normal traffic conditions for one year, having carried 9 million gross tonnes. As the installation took place under early winter conditions the rails were welded without being de-stressed. In May 1993 the de-stressing was carried out, during which operation NSB really was able to verify that the capabilities of swift de-clipping and re-clipping claimed by the supplier were confirmed.

NSB, as part of its normal procedure, has run the track geometry measuring car over the section during spring and autumn 1993. After almost one year in service the section produced a perfect recording. In particular, the track gauge diagram is most impressive.

During the near future NSB will evaluate the experiences gained, to reach a decision on whether the FASTCLIP system is to be introduced as standard on our lines.
The development of Fastclip

It is generally accepted that most innovation in industry takes place gradually in small increments, over considerable periods of time. Such hard-won advances are however occasionally interrupted by a significant leap forward in technology. Advances in elastic rail fastening technology have followed this pattern, but during the last three decades nothing has appeared which could be considered a radical innovation.

Early railway reactions to "Pendril FASTCLIP" suggest that history may well judge it to be such an innovation. It is the world's first fully captive, pre-assembled, fully automated unbonded elastic rail fastening.

In the article by Stein Lundgreen of Norwegian State Railways, a sense of anticipation is evident, in particular of logistical benefits during track laying and de-stressing. Although not mentioned, similar benefits could be expected during rail and pad changing.

Two FASTCLIP assemblies have been developed and tested in track to date. A European assembly, as installed in Norway, generating 20kN clamping force per rail seat from ø 17mm clips, and a heavy haul version, generating 25kN per rail seat from ø 16mm clips.

By 1993 FASTCLIP installations had taken place in Norway, Finland, Great Britain, and the USA. Further trial installations in Europe, the United States and Australia are expected to take place in 1994. These installations have followed a three year period of development and comprehensive laboratory testing. Laboratory testing has been more exacting than on any known rail fastening development, and was designed to confirm that the criteria for success had been met or exceeded.

The test programme was based on AREA Chapter 1B, modified where necessary to reflect experience derived from on-track recording and from laboratory simulation of on-track conditions. The resulting tests were not only more severe than standard European and American tests, but included improved test methods not currently applied in internationally accepted testing procedures.

As an illustration, the generally accepted fatigue endurance limit of a clip is ø 0.5mm. The design criterion set for Pendril FASTCLIP was ø 0.75mm to reflect the maximum repeated rail deflections measured in Pendril's on-track programme. This target was comfortably exceeded by FASTCLIP.

The optimal use of torque in the round bar was made possible by a unique finite element analysis model, developed by Pendril, which shows different levels of stress in the bar in different colours.

Finite element analysis.

Fatigue test machine.

Inclined Dynamic Test assembly at 45° to the horizontal.
Sleepers – Single or Twin?

Two-block sleepers have been used for many years on both ballasted and non-ballasted tracks. In recent years their use in ballasted tracks has declined, but the number of applications in non-ballasted track is increasing. "Booted" twin-block sleepers, with or without tie bars, are in use on some of the most modern railways. Problems of rail corrugation on such track forms, which had once been a cause for concern, are now well understood and can be avoided by the use of the correct combinations of sleeper mass and rail pad and boot stiffness. Examples from Europe and North America are described in detail.

Two of the world's most modern Light Rail Systems incorporate forms of twin-block sleepers for the rail support on sections of track – one ballasted, one unballasted.

The ballasted track form of the Sheffield Supertram now under construction consists of twin-block sleepers, connected with a steel angle tie bar, supporting the BS 86 (88 lb/yd) (40kg/m) rails at 790mm centres (50mm in curves). The blocks, manufactured by Stanton-Bonna of Britain (in collaboration with Sateba of France) incorporate Pandrol shoulders, EVA rail pads and 'w' type clips. The Stanton-Bonna sleepers are probably the first twin-block sleepers to be manufactured in quantity in Britain; they have previously supplied the sleepers used in the Channel Tunnel terminal in Folkestone.

Over in St. Louis, Missouri, USA, the popular light rail system, which opened for service on 31 July 1993, has a non-ballast track form in the downtown area with Sonneviste LVT twin pre-cast concrete blocks supported on resilient pads held in place by rubber boots fitted over the lower part of the blocks. The bolted blocks are surrounded by an in-situ mass concrete base, which holds the blocks to line, level and gauge. The rails are 129lb/yd (66kg/m), and are placed on 6.5mm Pandrol Dimplid EVA rail pads. Rail clips are Pandrol 'e' type held by shoulders cast into the blocks at 760mm centres.

Development of the Twin-Block Sleeper

The history of the twin-block sleeper goes back to the beginning of the century. Before World War I they were used by railways in Hungary and Pakistan to a
Grinding Machine Development at Pandrol Jackson

At the Laddington, Michigan plant of Pandrol Jackson Inc., a new transit grinder to meet the requirements of the Hong Kong Mass Transit Railway Corporation has been designed, built and delivered. The article provides a general description of the train and its operating features.

Since the early 1980’s, the engineering department of Pandrol Jackson Inc. (and Jackson Jordan Inc. which preceded it) has dedicated a great deal of effort to gaining an understanding of the mechanisms involved in grinding rail with conventional grindstones and the effects of the behaviour of the components of the system and the manner in which they operate (like, advance speed, contact pressure etc.) on the finished result. Early work concentrated on relatively small units for points and crossings, grinding from which single unit, purpose designed, transit grinders were developed for BART and the Vancouver SkyTrain of BC Transit. More recently, in response to a contract from the Hong Kong Mass Transit Railway Corporation, a three-unit 16 stone grinding train has been designed, built and delivered. This unit incorporates rail measuring, dust collection and pollution control equipment.

The "Hong Kong Grinder" is designed for bi-directional working with operating cars at each end. Each cab is pressurised to deter the ingress of grinding dust, and equipped with an efficient air conditioning/heating unit to provide a suitable environment for both the train operators and the electronic control equipment.

Angulation and grinding pressure of each grinding motor is directed, controlled and monitored by a computer which also controls obstacle clearance and monitors operating functions throughout the unit.

Two rail measuring systems are provided to record rail corrugation and profile. Corrugation is measured mechanically in a carriage mounted on a group of rollers spaced to provide an accurate rolling datum from which the relative vertical movement of up to three wheel followers can be very accurately measured using conventional eddy current displacement transducers. The transverse profiles are measured with an optical linear system where the image generated by a narrow beam of laser light directed across the rail head is...
Development of the Promorail “Type PR3” Track Fastening

The Promorail PR3 rail fastening is a resilient, threadless fastening which has been developed for automated installation. This simplified fastening system was designed to provide a self-tensioning spring clip fastening system with similar characteristics to the existing traditional threaded fastening, as used on SNCF. Two trials lengths have been installed on SNCF by SECEO/Desguenues et Ciral.

On 6th January 1993 Pandrol Rail Fastenings Limited acquired a controlling interest in Societé Industrielle de Wallers (SIW) and Promorail.

It was considered that it was necessary to develop a self-tensioning spring clip that provided similar characteristics to the traditional threaded fastening system used by the French National Railways. The main features of the fastening system are:

- Automated installation.
- No screw threads with fastening components.
- Large installed deflection of spring clip to minimise variations in rail component production tolerances. Features within a modern rail fastening system that will provide full restraint of the rail.

The above guidelines were considered and fully met during the development of the PR3 fastening system.

The PR3 fastening system can be considered as being in two parts. The initial components are pre-assembled at the time of manufacture of the concrete sleeper. Four cast ductile iron shoulders are cast into the concrete sleeper during manufacture. A plastic side post insulator is located within the gauge face of each shoulder after the concrete sleeper has cured and a resilient rail pad is glued to each rail seat.

The second portion of the assembly consists of the four spring clips per sleeper set which have an insulating plastic liner pre-assembled. The key attributes of the assembly can be unscrewed as:

- The cast shoulder provides the necessary anchorage for the PR3 clip. In addition, the profile hole within the shoulder frame is used by the automated clip installation machine to centralise the rail within the rail seat prior to application of the PR3 clip.
- The two separate insulating components within the fastenings can be manufactured from differing materials to suit the individual requirements and each has been designed to be captive within their respective fastening positions. The side post insulator can be produced with variable thickness for gauge adjustment purposes and can be replaced in track if wear occurs in service.
- The resilient rubber rail pad provides the necessary electrical insulation between rail and concrete sleeper as well as preventing the rail from abrading the concrete rail seat surface. The 10mm thickness grooved profile provides the desired level of resilience and vibration suppression.
- The PR3 resilient clip was developed as a self-tensioning spring element which when installed into the assembly will generate a clamping force onto the rail that will prevent all rail movements.

Advantages of the PR3 (fastening assembly)

- The only loose component is the spring clip.
- The spring clip can be installed by an automatic machine with magazine feed.
- The concrete sleepers can be handled by the profiled holes in the shoulder heads.
- Each spring clip exerts a 1 tonne load onto the rail.
- The PR3 spring clip incorporates secondary stiffness that prevents rail rotation beyond that likely under normal operating conditions.
- The good working deflection of the PR3 clip ensures that the rail is at all times fully restrained against movement.
- Two part insulator provides good electrical insulation of the rail.
- Very high fatigue resistance of the spring clip ensures a long in-track life.
- The good working deflection of the PR3 clip ensures a high level of toe loading is applied to the rail for the full range of component production tolerances.
- Total mechanisation of track installation can be achieved with the current range of track laydown equipment with fastening application integrated within the system.

The PR3 fastening is a cost effective system economically comparable with other alternative fastenings. Installation of the system is therefore simplified as the concrete sleepers are delivered to the track site with side post insulators and rail seat pads attached. The rails are laid over the sleepers with guidance being provided by the profile of the shoulder heads and the application of the PR3 self-tensioning spring clip is fully mechanised. The machine locates the concrete sleeper by inserting pins through the profiled holes in the rail of the shoulder heads. If the rail is not centrally located within the rail seat then the machine will re-adjust the position of the sleeper. When the rail is centralised the four PR3 clips are automatically inserted into their respective shoulders and the mechanisms retracted for indexing to the adjacent sleeper where the process is repeated.

Hand tools are also available for individual installation or extraction of PR3 clips.
Track Trials of Promorail PR3 Fastenings

The company SECO/Despontines of Girar has installed two trial lengths on SNCF using VAX 141 sleepers with the PROMORAIL PR3 fastening system as follows:

For the Paris-St. Lazare region, in the framework of the creation of a third track on the Paris-Le Havre line:

- 1090 metres of track
- Installation carried out between 15th and 20th January, 1993
- Intended traffic speed: 160 km/h
- Track slightly curved (radius > 2,500 metres)
- Additional track lifting and levelling carried out by means of a standard heavy-duty tamping and lining machine

For the Paris-Nord region, in the framework of the Grande Couronne Bobigny-Huilly:

- 115 metres of track
- Work carried out on 17th August 1993
- Curved track (radius ~ 480 metres)
- Additional track lifting and levelling carried out by means of a standard heavy-duty tamping and lining machine

Rail Flaw Detection using Modern Pattern Recognition Techniques

Rail flaw detection techniques can be divided into two broad categories. One is the traditional method of 'interrupt and verify' testing used widely in North America. This involves having the testing system highlight ultrasonic detection events by channel either on a paper tape or a video tape event recorder. Each individual channel relates to an area within the rail (e.g. head, web or base) and any reflections therein indicate some ultrasonic event has occurred. Such events are not necessarily indicative of defects. The operator continuously reviews the output from the system and decides when it is necessary to verify if the events observed indicate a true defect in the rail. This is accomplished by either stopping the vehicle or relaying the message to a chase vehicle and having someone perform an in-situ verification using a manual flaw detection instrument. Such testing is also called subjective testing because of the large element of subjectivity involved in the operator's decision making process.

The second broad category of rail testing is used for higher speed testing where defect populations are lower, track availability is limited and/or confirmation and remedial actions are not immediately required by regulatory authorities. A key element of such testing is that the test system (and not the operator) should identify the defect. Hence this type is generally known as objective testing.

In order for the system to identify the defect, some form of knowledge based system using pattern recognition techniques must be used and, typically, a post processing environment using relatively large data processing capabilities is employed.

Pandrol Jackson Technologies (PT) has recently developed a fully commercialised rail testing system called SYS-1000 which tests objectively in real time with a highly sophisticated pattern recognition capability. To achieve this end, the technology uses a multi-computer based distributed processing system. The system identifies the defect at speeds of up to 40 km/h, presents it in a modified PIT Scan® mode, paints the rail and shows the appropriate defect icon for the defect on a permanent video record. PIT Scan® is a modified type of BScan presentation which presents the rail in longitudinal profile and adds the appropriate recognition icons in real time. A typical screen output is shown in Figure 1. The video record can be replayed at any time during the test and the operator can review the more critical defects quickly and initiate remedial actions if necessary prior to the end of the test run.

At the end of the test run, a complete report of the day's activities can then be downloaded if required to the railroad's in-house computers.

SYS-1000® uses twelve testing and two control channels per rail. These are contained in two distinct groups of seven which are located in two wheel mounted transducer units located 22.5° (570mm) apart on the testing carriage. The transducers are oriented at various angles and directed to avoid echo "Crosstalk" and shown in Figure 2. Each wheel contains a three element 70 degree array located to
give complete coverage to the head of the rail, a 45 degree transducer aimed at the web area, a side looker oriented to look across the head and a zero channel for base and control.

A key element in any pattern recognition system is the spatial transformation of the data from each ultrasonic channel focused on a given rail. While each of the 12 channels is pulsed at the same instant, the echoes generated are coming from a wide variety of separate locations along the rail at any given time. These individual data elements must thus be stored until all echo possibilities from a given 1.5mm wide longitudinal slice of rail have been collected. This storage window is usually just less than 1 metre of actual travel along the head of the rail. Once this point has been passed, the data is spatially transformed and a "picture" of the actual longitudinal slice is stored within the system. This spatially transformed data, along with those of its adjacent slices provides the input to the pattern recognition algorithms for comparison with pre-programmed sets of known recognisers.

The recognisers themselves are derived from rigorous theoretical considerations and the literature on this subject is extensive in other industries. PTT has adopted these proven techniques to rail and specific patterns have been developed for each known type of rail defect. These have subsequently been modified, based on empirical data from known defects. The artificial and real which have already been catalogued in the field. They are then compared in real time to the data from the spatially transformed ultrasonic echo patterns received and SY5-1000® then decides, also in real time, whether a defect exists at that location or not. If a true defect is found to exist, the software instantly sends a signal to a set of paint guns which then spray the rail at the defect's actual location.

The process of verifying and cataloguing real defects is ongoing and further fine tuning of the recognisers will inevitably result.

However, the system is working well and in recent proof tests detectability and repeatability ratios in excess of 97% were achieved at a variety of speeds. Work is still progressing on recognisers for the identification of benign track features such as frigs, switch points etc. which are ultrasonically very active. The presence of these major features is currently input by an operator with a remote hand held keypad. Ideally, they would be recognised within the system thereby avoiding operator input.

Four SY5-1000® cars have now been commissioned for the Chinese National Railway and another unit is currently under construction. Two of the cars were manufactured by Pandrol Jackson at their Ludington, Michigan and Syracuse, New York plants. The remaining three were built under subcontract to PTT by the car building shops at Baogi, Shanghai Province, China. When all are in service, four separate Chinese railroad administrations will have use of this world leading technology. Another system has been installed on a multi-function vehicle for Singapore MRT which will shortly go into service.

![Figure 1: Output data from a typical rail spot.](image1)

![Figure 2: Ultrasonic Wheel and Transducer Arrangement.](image2)

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An Adjustable Assembly for the Japanese Shinkansen Line

The new ballasted concrete slab track system used on the Shinkansen network requires a rail fastening that permits lateral and vertical adjustment of the rail (to compensate for slight misalignments from slab to slab) and controlled longitudinal rail creep (to prevent thermal stresses in the rail from damaging the concrete 'slabs' that hold the slabs in place).

The self-contained Pandrol adjustable assembly uses two long, tapered insulators to provide lateral adjustment of the rail and packings beneath the rail to provide vertical adjustment. Clip toe height is maintained constant too lead. A combination of low clamping force (approximately 350 kgf per rail clip) and controlled creep resistance (approximately 500 kpfm/rev) is achieved using a low toe load clip together with a rubber rail pad incorporating a stainless steel rail plate (bonded to the upper surface of the pad to control the friction between rail and support).

The Pandrol adjustable assembly is currently under test in the Haruna Tunnel, Takanaki, on the Joetsu Shinkansen Line.

Adjustable Assembly undergoing Longitudinal Creep Test.
Self-contained design

The Pandro adjustable assembly is entirely self-contained. Two long, tapered insulators are used to alter the lateral position of the rail, relative to the shoulders. These are held in place by serrations that locate into corresponding grooves in the shoulders.

Vertical adjustments are made using packings beneath the rail pad, which lift the rail to the required height, then, to maintain a constant toe load, eccentric sleeves in the shoulder housings are rotated to adjust the toe height of the clip. Settings marked on the shoulder sleeve (0, 2, 4...) indicate height in millimetres – so if the packing is 10 mm, the sleeve is rotated until '10' is aligned with the top of the shoulder.

Adjustable Assembly undergoing Insulation Sensitivity Strength Test.

Diagram showing method of shimming for vertical adjustment of rail.

Diagram showing tapered insulator for lateral adjustment of rail.
Developments in equipment and computing are turning the possibility of automating the whole rail grinding process into reality. Rail profiles can now be dynamically measured by laser optical devices to accuracies from which grinding requirements can be determined. Software programmes, developed and refined from numerous field measurements, can define the grinding stone pattern needed to achieve a particular rail profile. This article describes the work being undertaken at Pandrol Jackson to link these developments and develop a comprehensive grinding planning and operating system.

Since 1994 Pandrol Jackson engineers have been measuring rail corrugations and rail profile with their RA-204 rail analyzer vehicle. The data from the RA-204 has been used by many railroads in the US for preparing their rail grinding programs. In order to assist Pandrol Jackson customers and to automate the grinding planning process, PI engineers also developed computer software that used the RA-204 data as input to generate grinding plans. The RA-204 vehicle used an arrangement of mechanical wheels on the railhead to measure corrugations, the radius, and the cant of the running surface of the rail. While this mechanical system worked well, it required frequent adjustments and calibration to maintain accuracy of the measurement. Today, using advances in optical laser measurement equipment, it is possible to obtain, in most circumstances, accurate non-contact profile measurements. This new ‘Laserrail’ system produces a graphical display of the railhead profile as well as accurate x-y coordinates for 200 points on the railhead.

The Laserrail system is in operation on track geometry cars in several North American railroads, CP, Connell, CSX and Santa Fe. Also, two second hand PI engineers have currently incorporated this new technology into the recently delivered Hong Kong Transit Grinder and the Magnus Grinding train development. With the advent of this new system on geometry cars it is now possible to use data directly from the geometry car to plan grinding. The accuracy of the Laserdata and its availability on the above railroads has made computerized planning of grinding a very viable possibility.

Software originally written to plan rail grinding with the RA-204’s mechanically derived data has recently been upgraded for use with the Laserdata. Two software packages are available, the Grinding Planning System (GPS) and the Graphical Grinding Program Editor (GGPE). The GPS software plans grinding for a discrete segment of track; i.e. a curve or a specific length of tangent track. The GGPE software provides a means of preparing a global grinding plan using the GPS output as a starting point.

GPS software identifies areas of the railroad that require grinding. The profiles are aligned in the software and combined to result in a composite profile for the two rails. These composite profiles characterize the track for grinding purposes.

Once these profiles are known, they are compared against limits set by the customer for the running surface radius and cant. If the particular curve or tangent segment is outside the pre-set limits, the

No additional components are required. The assembly provides lateral adjustment of up to 10 mm, in 1 mm increments, and vertical adjustment of up to 10 mm. In increments of 2 mm.

Achieving controlled rail creep

The EIR specification calls for a rail clamping force of approximately 170 kgf per rail clip and a creep resistance of approximately 500 kN/metre/rail. The Pandrol adjustable assembly combines a low toe load clip with a rubber rail pad incorporating a stainless steel rail plate (bonded to the upper surface of the pad to control the friction between rail and support) to provide the controlled rail creep required.

The specially designed Pandrol brand rail clip type e1881 generates a toe load of approximately 300 kgf at a toe deflection of 10 mm. Toe load measurements taken from six clips, installed in the adjustable assembly with the notched sleeve in different settings, showed that vertical adjustments have negligible effect on toe load.
equipment to double track when moving from one section of track to the next.

The GPS software features pull-down menus that make it easy for the user to control the many variables in the typical grinding planning environment. These variables include such areas as:

- Minimum allowable grinding speed
- Maximum allowable number of grinding passes
- Minimum length of tangent track
- Distance between adjacent curves
- Specific grinding plan
- Grinding pattern selection
- Metal removal tables
- Locations of running band on tangent, low rail, high rail, and many others.

GGPE

GGPE software obtains the information from the GPS system and packages it in a user-friendly track chart format. These individual grinding plans are transformed into a grinding program by the GGPE system. Pandrol Jackson customers use the GGPE to translate grinding recommendations into railroad-specific instructions. This is accomplished on a simplified track profile which indicates track event information, locations of water sources, and tie-up locations. The amount of track time required for grinding and for light running is also displayed and totalled on the chart.

A major feature of the GGPE system is that it allows for easy editing of any part of the grinding plan, or for bulk editing of the entire plan. This feature allows the maintenance planner to quickly evaluate how changes in the grinding plan affect the overall grinding budget. Modifications to the plan are easily accomplished by indicating the area of interest and the changes required such as, add/remove/multiply a pass or change speed.

Railroads continually express interest in using computerized grinding planning. This is primarily due to the benefits of using these new planning tools:

- Firstly it is possible to establish a detailed program across the entire railroad. When grinding decisions are made using objective data as a basis, all segments of the railroad can be treated equally. Or, if preferred, it also offers the ability to program certain areas such as, high tonnage lines with tighter limits than other areas of the railroad to ensure that these areas receive the proper grinding attention.
- Secondly, use of the GPS system allows the railroad gains in productivity because it ensures that work will be done on a logical basis where it is needed the most.
- Thirdly, it allows centralized control of the grinding program and the ability to establish consistent goals.

Fourthly, it provides limiting values which may be adjusted to provide a fit between the amount of grinding forecast and the budget.

The GPS and GGPE are state of the art software programs. Pandrol Jackson is looking forward to incorporating this type of computerized rail grinding planning more widely on both American and International Railways.
A Test Rig to Measure Railpad Dynamic Stiffness

A new laboratory rig has been developed which, for the first time, provides a quick, easy, and reliable test of the dynamic characteristics of railpads under conditions representative of those encountered on track.

The article describes how the need for laboratory tests of railpad dynamic performance first evolved, and some of the earlier test methods which were developed to meet this need. Each of these tests suffers from some drawbacks, which meant that a new approach was required. The design concept for the new rig is explained, indicating how this leads to a test which overcomes many of the disadvantages of previous methods.

Sample test results from the new rig are shown which illustrate the importance of measuring railpad characteristics under realistic conditions.

On all railways dynamic forces are generated at the wheel-rail contact as a result of irregularities on the surfaces of the wheels and the rail. These dynamic forces generally increase as train speeds increase, and can be very large on modern high speed track. Dynamic forces are transmitted through the railpad into the supporting structure, which can lead to cracking of the sleepers and rapid deterioration of the ballast. Many track engineers are familiar with this concept, and add a ‘dynamic overload factor’ to their calculations when designing or specifying new track or track components. This factor is very difficult to define, but is usually taken to be two to three times the static load applied by the weight of the trains. The implications of dynamic loading on the cost of track components for high speed track are therefore very significant. For example, sleeper designs will need to have up to three or four times the flexural strength which consideration of static loads alone would suggest. So any measures which can reduce dynamic forces can provide valuable savings in the initial cost of the track components. Alternatively, for a given sleeper design, if dynamic forces can be attenuated then the size of allowable wheel and rail defects can be increased – which implies longer maintenance cycles and reduced maintenance costs.

Ten or fifteen years ago a number of cases were reported where cracks had been found in concrete sleepers on relatively high speed passenger lines. Simple measurements determined that the highest sleeper strains were associated with wheelflats and wheel irregularities – in other words that the problem was caused by excessive dynamic forces. It was found that changing the type of railpads used seemed to have a significant influence on the level of strains measured in track under wheelflats. The promise of reducing dynamic forces through changing the railpad was extremely attractive, since the pad could be easily replaced and was relatively inexpensive compared to the cost of the whole track structure. In order to investigate which railpads had the greatest effect, simple laboratory tests were designed which allowed different designs to be compared. One test rig was developed at the Battelle Columbus Laboratories. This attempted to reproduce under controlled conditions in the laboratory the type of dynamic loads which are generated by wheel irregularities on track. A test railpad was placed between a short length of rail and a sleeper testing on a simple support. A weight was dropped on the rail, and the resulting strain in the sleeper was measured. By repeated trials a standard weight and drop height was found which produced similar levels of strain to those which had been measured in track under typical wheel irregularities. Various different railpads could then be tested in turn, and the peak level of strain measured under this standardized impact load measured for each type. The performance of each pad was then indicated by an attenuation figure representing the reduction in peak strain as compared to some reference pad type – normally a plain surface 5mm EVA pad.

The Battelle type rig provides a functional test which allows different railpads to be compared and ranked. Where extensive track trials have been conducted on pads which have also been tested on this type of rig, it has been found that the ranking of pads obtained in the laboratory is an accurate indication of that which is found in track. However, this type of test does suffer from a number of disadvantages. The measurement of a peak value of strain is very prone to error. Slightly different peak levels are often measured even between two successive drops of the weight under nominally identical conditions. Over a longer time period small changes in the rig can lead to larger differences in the peak strains recorded. For instance, in rigs where the sleeper is supported in a tank of ballast chippings, the support conditions can change slowly with time. Inaccurate results can be generated unless great care is taken in the use of the rig. Since the largest strains in track usually occur when a wheelflat strikes directly over the sleeper, it is naturally desirable to test the railpads in...
Heavy Haul Track Research

Pandrol International is continuing research into the effects of very high traction forces on track components. In recent tests in North America, measurements were made of longitudinal and vertical rail movements, and longitudinal rail strain under 15000 tonne coal trains moving up gradients of up to 1.4%. The results were compared with laboratory creep tests and non-linear finite element analysis (using PROLIS 2.1 software) in order to study the influence of rail pad and clip design on the ability of the track to withstand these severe loads.

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STIFFNESS OF EXPERIMENTAL 10MM STUDDED RUBBER RAILPADS

- Dynamic Test Rig
- Static Load-Deflection Test

**Graph:**
- **Stiffness (MN/mm):**
  - 0
  - 100
  - 200
  - 300
  - 400
  - 500
  - 600
- **Load (kN):**
  - 0
  - 25
  - 50
  - 75
  - 100
  - 125

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A loaded condition, to represent the weight of the train. To apply this load to the pad in the Battelle type rig it is necessary to add a large loading frame which itself modifies the dynamics of the test rig and influences the results obtained. Finally, it is difficult to test pads of different thicknesses and which have been designed for different rail base widths. Often the pad has to be cut to size, or tested on top of metal shims to make its thickness up to the correct level for the sleeper assembly.

The Battelle type test is only capable of rating one railpad's performance relative to another—no absolute measure is obtained. However, at about the same time as these tests were first being developed, mathematical models of the dynamic behaviour of track began to describe in detail exactly how and why the railpad could have such profound influence on the dynamic loads transmitted into the sleeper. It became clear that short wavelength irregularities on the wheel, such as wheel flats, generate similar amplitudes of movement of the rail, regardless of the type of railpad. The high frequency dynamic force transmitted through the railpad to the sleeper is therefore roughly proportional to the dynamic stiffness of the pad. So it was the different dynamic stiffness values of different railpad designs which were being indicated (but not measured) in the Battelle test, and which were resulting in the different strain levels recorded in track. This suggested that a laboratory test which could measure the dynamic stiffness of the railpad, and at the same time overcome some of the problems associated with the Battelle type test, was required.

The simplest type of test which could be used to measure dynamic stiffness of a railpad would be to apply a dynamic force and measure the resulting deflection. But there are a number of drawbacks to this method—it depends on the accuracy of measurement of very small dynamic deflections, and the frequency at which large loads can be applied with a hydraulic actuator is limited to a few cycles per second (Hertz) rather than the hundreds of Hertz which are generated on track.

Instead a more novel approach has been adopted for the new 'resonance' test rig, which has been shown here—so called because the railpad stiffness is calculated from the resonant frequency of the rig. It has been based on a smaller experimental version, which proved the principle, but which was slow and cumbersome to use in practice. The new test rig allows the dynamic stiffness and damping of railpads to be measured under load and at high frequency. Because railpad stiffness is calculated from the frequency of vibrations, rather than from their magnitude, it is not sensitive to small changes in condition or to small measurement errors. The rig is quick and easy to operate, and gives repeatable results. It therefore represents a considerable advance over all previous means of measuring or assessing railpad dynamic performance.

The test railpads form the elastic element in a simple mass-spring system which is at the heart of the rig. The resonant frequency of the system depends on the stiffness of the railpads. Load is applied to the pads through large coil springs which isolate the system from the ground and from the rest of the rig. The stiffness and damping of the pads is calculated from the characteristics of the vibrations which result when a weight is dropped on to one corner of the test rig. A computer program measures the load applied to the pads, controls the dropping of the weight, monitors the resulting vibrations, and calculates and displays the dynamic stiffness and damping of the railpad. The load on the pads can be increased by driving the top plate of the rig down thousands of columns towards the base with a large electric motor. Pads of any thickness can be tested. They are simply placed on the bottom block at marked positions, and the required test load is then applied. Chains linking the top block to the top plate of the rig allow it to be lifted clear of the bottom block so that test pads can easily be removed and inserted.

Three identical pads are required for each test. This is because earlier experiments demonstrated that the rig had to be triangular in order to ensure that it could be made to vibrate in a predictable manner when struck in one corner. The rig has been calibrated so that pad stiffness can be accurately calculated from this prescribed vibration mode. Results show good agreement with those produced using the earlier experimental resonance rig and the dynamic load—deflection measurement method described above.

An example of the results which can be produced on the rig is shown here. The graph shows the dynamic stiffness of a 10mm studded natural rubber railpad as a function of normal load. The frequency at which each point on the graph is produced depends on the stiffness of the pad at that point—it ranges between about 70 and about 300 cycles per second. Also shown is the stiffness of the same pad under static loading. There is a more or less constant factor of two between the two stiffness values across the load range. For most materials it is found that the dynamic stiffness is substantially greater than the static stiffness, and in many cases the factor is rather larger than that for the studded rubber pad type shown. The graph shows the importance of measuring dynamic rather than static railpad stiffness, and of subjecting the pads to a load which represents conditions in track.
Empresa Colombiana de Vías Ferreas (FERROVIAS) required a simple yet effective rail fastening that could be installed on their Cuerasisaco hardwood sleepers to replace ageing timber sleepers with AREA tieplates and cut spike rail fixations.

Pandrol Ltd proposed the Gauge-Lock resilient rail fastening that had been initially developed for use on hardwood sleepers without the need for an intermediate metal baseplate.

The site selected for the trial was 105km from Bogota in the vicinity of a town named Villota. The single track with bi-directional operation had a nominal gauge of 944mm although through the curve selected for the trial the gauge would be increased up to 939mm (+15mm).

The existing track used 75 ASCE jointed rail for a maximum axle load of 18 tonnes although due to the condition of the track the FERROVIAS had restricted line speed to 25km/hr.

The new sleepers were pre-drilled for the Gauge-Lock fastenings at the local permanent way depot and then transported to site on the day of installation.

As the track refurbishment was to be carried out between trains it was proposed that sleepers were individually replaced with pre-assembly of the new fastenings so that disruption to the train schedules was kept to a minimum.

Two holes had to be drilled on each side of the rail to accept each fastening. A 14mm diameter hole was initially drilled adjacent to the edge of the rail to accept the front leg of the clip. Then a second hole of a diameter to suit the standard FERROVIAS screwspike was jig drilled in a position relative to the first hole to provide good gauge control along the full length of the centre leg and tension the clip to achieve the desired clamping force on the rail.

Additional rail anchors were needed to restrain the rail and the initial 40 sleeper installation has already demonstrated to FERROVIAS that substantial improvements in the track standard can be achieved leading to an increase in the line speed and the intervals at which maintenance of the track has to be carried out.