RailMeasurement

# Measurement products for rail corrugation (longitudinal profile)



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# 1. Summary

The *RailMeasurement* consortium have developed three different types of equipment for the measurement of longitudinal rail profile:

- *Corrugation Analysis Trolley (CAT)*

  The CAT is a portable instrument (weighing less than 15kg in total) for the accurate measurement of rail profile, and is typically used to measure rail for acoustics purposes and for quality assurance of rail grinding.

- *Rail Corrugation Analyser (RCA)*

  The RCA is a train-mounted instrument, designed to measure rail profile to accuracies sufficient to approve grinding work, and to determine the requirement for grinding on worn rail

- *High Speed Rail Corrugation Analyser (HSRCA)*

  The HSRCA is a train-mounted instrument like the RCA, but has been designed to carry out surveys of rail corrugation over extended lengths of track at high speed (80km/h or more)

Sections 2, 3 and 4 describe each of these instruments in more detail, whilst section 5 discusses the precision, accuracy and repeatability of all of the instruments.

Section 6 contains a list of references.

Finally, section 7 contains a specification of each of the instruments in the form of a comparison table.

# 2. Corrugation Analysis Trolley (CAT)

The **CAT** (Figure 1) is an extremely accurate instrument that can be used to measure rail for acoustics purposes and for Quality Assurance of rail grinding. It has the great attraction that it can be both used and carried by a single person: the equipment, when packed in a convenient box, weighs less than 15kg. There are few, if any, instruments that can measure metres of rail with similar accuracy and none, to our knowledge, which can be used conveniently by a single person.

This instrument is the most recent development of a piece of equipment made originally at Cambridge University, England, in the 1970s for measuring corrugation. A further development was made in the late 1980s to make portable corrugation-measuring equipment for Australian National railways. This equipment is still used routinely on Australian railways. The first prototype of the present CAT was produced in 1997. Since then, examples of the present equipment have been used routinely and reliably for corrugation surveys, Quality Assurance work following grinding on all types of railway line, and for acoustics work.

The CAT is an appropriate instrument for measurement of rails to assess roughness in accordance with the recommendations of the provisional International Standard ISO 3095 [4]. Indeed it far exceeds the requirements of this Standard insofar as hundreds of metres of rail can be measured continuously, accurately and quickly through a test site, rather than simply isolated lengths of about 1m. Such a continuous measurement permits kurtosis analysis to be used to determine whether individual 1m lengths of track are typical of a full test site.

*Figure 1: Corrugation Analysis Trolley (CAT) in use*

With relatively minor modifications, the portable CAT could also be used to measure wheel profiles.

Output from the CAT is available in several formats appropriate to both grinding and acoustics work: amplitude vs. distance, one-third octave band spectra and exceedences are amongst many standard functions. Examples of spectra of successive measurements of the same, extremely smooth rail are shown in Figure 2, demonstrating the CAT's excellent repeatability even at wavelengths of a few millimetres and amplitudes of less than a micron. These spectra are plotted relative to that given in the draft ISO 3095 [4]. The capabilities of the CAT far exceed the narrow requirements of this draft Standard. Accuracy and repeatability of CAT measurements is discussed further in Section 5.

Further information on the CAT and in particular on its use for monitoring corrugation and for grinding specifications is given in references [1] and [2].

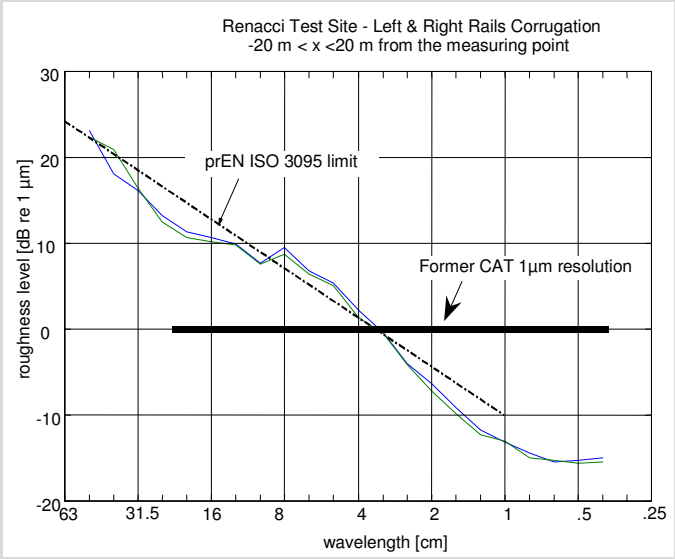



*Figure 2: Spectra of rail profile c.f. spectrum from draft ISO 3095, showing repeatability of CAT measurements*[1]

[1] Data obtained by Dr Andrea Bracciali of the University of Florence, and shown here with his permission.

# 3. Rail Corrugation Analyser (RCA)

The **RCA** is a train-mounted instrument that has been designed for measuring the longitudinal rail profile to accuracies that are sufficient to approve grinding work and to determine whether rail should be ground. Simultaneous measurement of both rails is possible at moderate speeds (typically 5km/h) with an accuracy that is only slightly poorer than that of the CAT. Measurement at higher speeds (up to 20km/h) is possible with consequently reduced accuracy. The RCA is calibrated by using both it and the CAT to measure the same length of track (Section 5). This instrument is appropriate for surveying corrugation severity on relatively small railway systems, and has been used for this purpose. It is also frequently used for approval of grinding work. An example of an RCA measurement over 200m of a site where the inside (Left) rail is corrugated is shown in Figure 3.

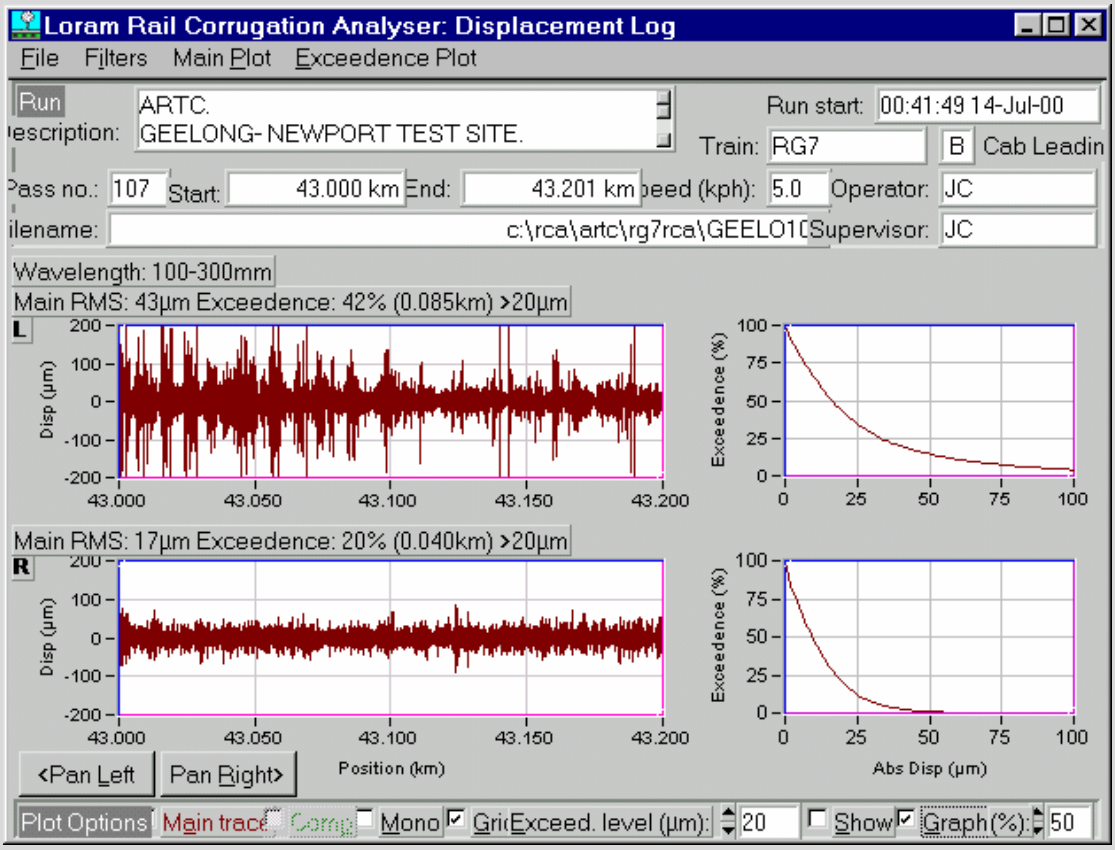



*Figure 3: Sample output from RCA software, showing filtered displacement (100-300mm) and exceedences*

We are currently engaged with German Railways (DBAG) in the procedure to obtain approval of the RCA as a suitable instrument to measure corrugation before and after rail grinding.

# 4. High Speed Rail Corrugation Analyser (HSRCA)

The **HSRCA** is an instrument that is designed for corrugation surveys of a complete and fairly large railway system at relatively high speed (typically 80km/h or more). It is extremely robust and reliable: the earliest version of our system has been used routinely in Australia since 1987, without significant need for maintenance (see reference [3]). The most recent version is used routinely by the state railways in Italy (FS), while other versions have been used in Poland and in Israel. Calibration of the HSRCA is verified by using both it and the CAT to measure the same length of track.

One of the most useful forms of output from the HSRCA, taken from measurements made over a 35km length of track in Italy, is illustrated in Figure 4. The upper and lower parts of this Figure show data for the left and right hand rails respectively. The data shown are the so-called "percentage exceedences" for corrugation in different wavelength ranges as functions of the corrugation amplitude in microns SQM (i.e. RMS or root-mean-square). For example, for the left hand rail in the 30-100mm wavelength range, corrugation exceeded 20 microns RMS over about 50% of the 35km stretch of track, and 40 microns RMS over about 10% of the track length. Presentation of data in this format helps to establish simple objective criteria for grinding such as, "Any 200m length of track should be ground when corrugation on either rail in the 30-100mm wavelength range exceeds an amplitude of 10 microns RMS over at least 50% of the site, or 20 microns RMS in the 100-300mm wavelength range." [2]

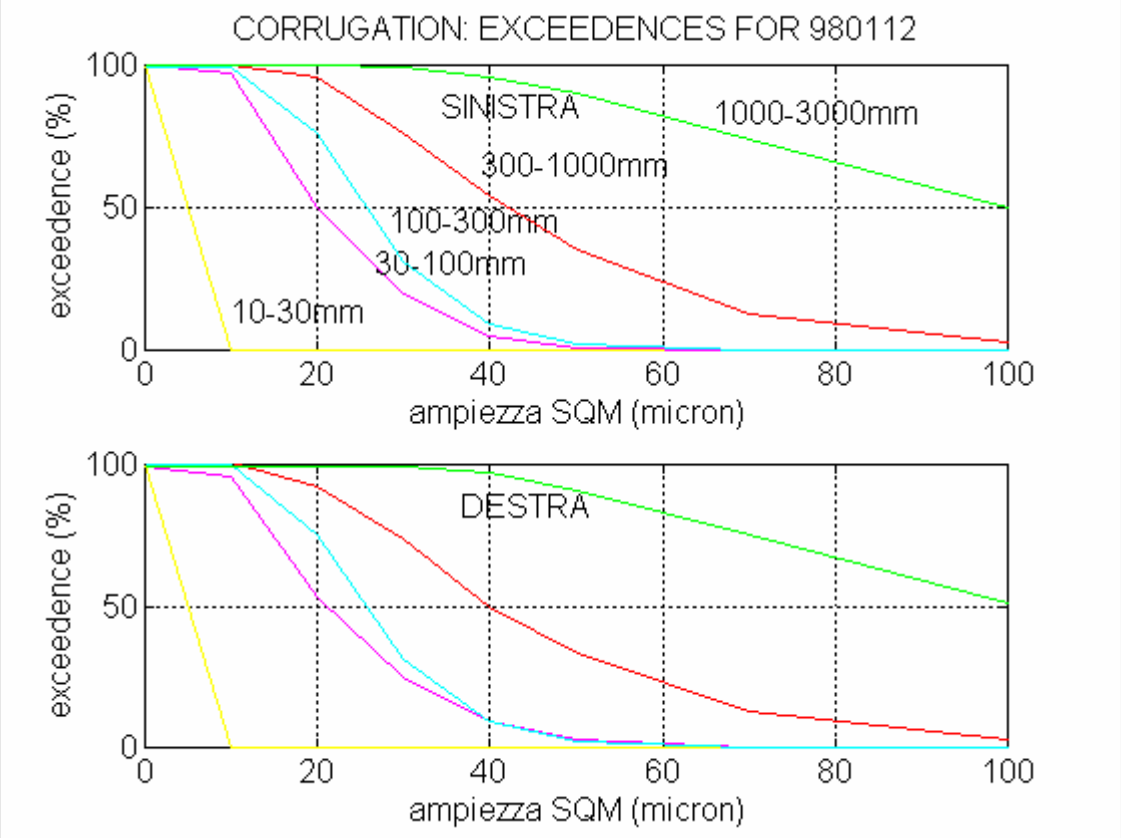



*Figure 4: Sample of exceedence data from HSRCA*

[2] By these criteria, one would expect that most of the length of track measured here would require grinding.

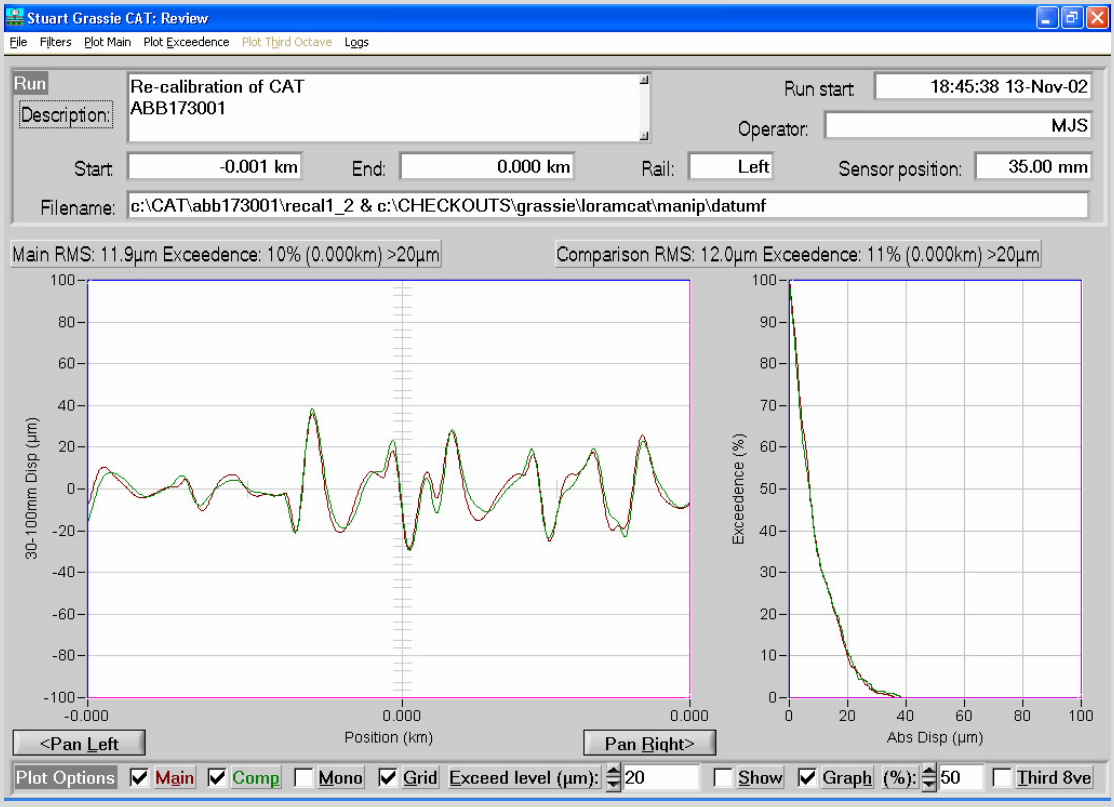
# 5. Software, measurement accuracy, precision and repeatability

All three measuring systems use proprietary software that has been developed in close collaboration with our clients to give output appropriate to their various requirements. The software is updated frequently with new features.

Both the CAT and the RCA store raw profile data from which measurement statistics are derived. The CAT stores rail profile data at intervals of 1mm or 2mm (selectable), and with a precision of 0.01 micron. The RCA stores rail profile data at intervals of 2mm and with a precision of 1 micron. Because the typical lengths of rail measured by the HSRCA are much greater than those of the CAT or RCA, the HSRCA does not store the raw rail profile data, only the measurement statistics derived in real time from this data.

The severity of corrugation can be assessed objectively using the so-called "percentage exceedence". This principle is currently embodied in a draft European Standard for rail grinding and reprofiling, prEN 13231-3 [5]. Calculation of percentage exceedences is included in software for all three measuring systems.

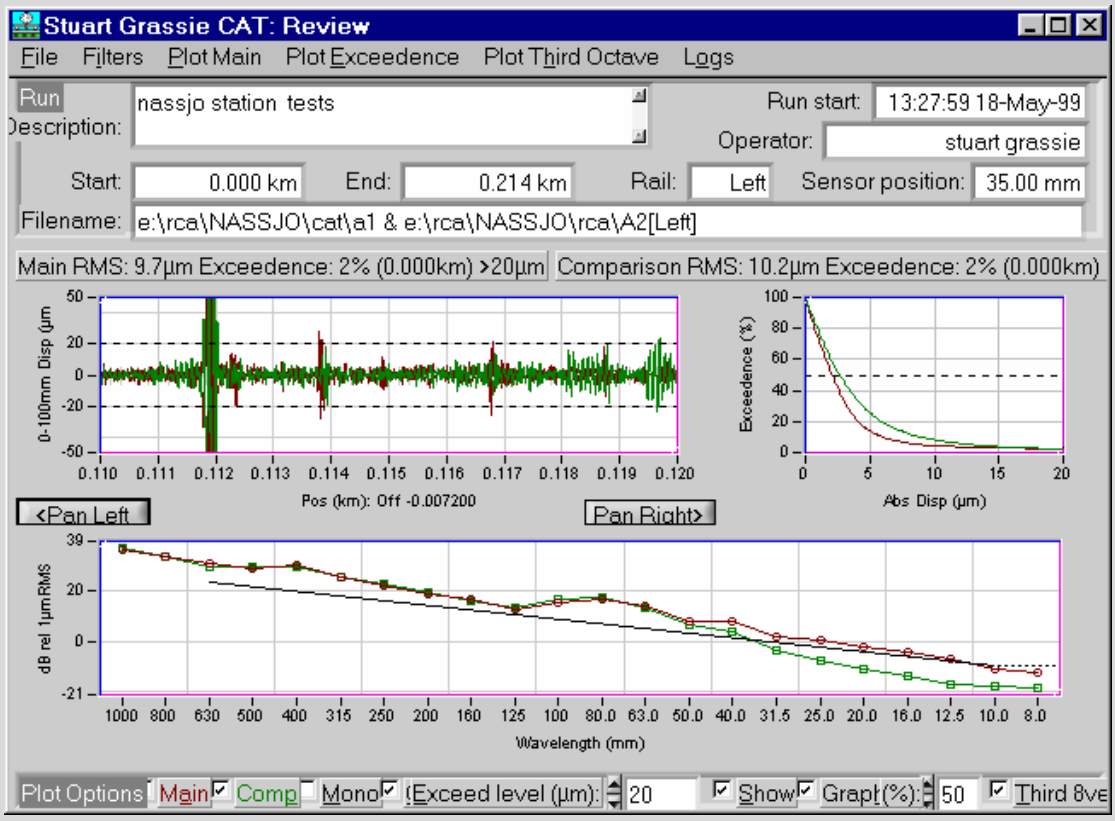
One of the simplest forms of output from the CAT software is illustrated in Figure 5, which also illustrates the accuracy of the instrument: the Figure shows a comparison between filtered profiles of a 0.9m long reference beam measured with the CAT and with a Coordinate Measuring Machine (CMM). We are not aware of any other equipment for which similar comparisons have been made in order to assess accuracy rather than simply repeatability.




*Note: Length of beam measured = 0.9m (+/-0.45m), hence rounding to 0.000km on x axis*

*FIGURE 5 Measurements of reference beam with CAT and Coordinate Measuring Machine*

As the calibration of the CAT can be independently checked, it can be used as a reference instrument to verify the performance of the RCA and HSRCA. An example of the type of comparison that can be made directly in the CAT software is illustrated in Figure 6. In this example, the filtered profile, percentage exceedence and one-third octave spectra are compared for measurements made using the RCA and the CAT over the same 10m length of track. Similar comparisons can be made for lengths of track from fractions of a metre (e.g. to examine individual irregularities) to kilometres.




- *filtered displacement in 30-100mm wavelength range*
- *one-third octave spectrum of "raw" (unfiltered) profile*
- *percentage exceedence of 30-100mm filtered profile*

*Figure 6: Comparison of RCA and CAT output over 10m of track*

# 6. References

1 Grassie SL, Saxon MJ and Smith JD, "Measurement of longitudinal rail irregularities and criteria for acceptable grinding", Journal of Sound and Vibration, 1999, 227, 949-964

2 Grassie SL, Saxon MJ and Smith JD, "Measurement of irregularities underpins grinding criteria", Railway Gazette International, March 1998, pp163-166

3 Grassie SL, "Corrugation of Australian National: cause, measurement and rectification", 4th Intnl Heavy Haul Railways Conference, Brisbane, Instn of Engrs Australia, 1989

4 “Measurement of noise emitted by railbound vehicles”, draft of provisional EN ISO 3095, European Committee for Standardisation, Brussels, April 1999

5 “Acceptance of rail grinding, milling and planing work in track”, draft of provisional EN 13231-3, European Committee for Standardisation, Brussels, October 2000

# 7. Specifications and features of instruments

The features and specifications of equipment given on the following pages are illustrative only. They are not a guarantee of performance in a particular case. For more information, please contact *RailMeasurement* (see the front page for contact details).

| Feature | CAT | RCA | HSRCA |
|---|---|---|---|
| **Weight & portability** | Portable, 7kg instrument, 11kg when in case<br>Operated by one person | Not portable: train mounted | Not portable: train mounted |
| **Measuring speed** | Walking speed: 2-5km/h | Up to 20km/h demonstrated | Typically 60-100km/h; lower speed possible with reduced accuracy, particularly at long wavelengths |
| **Measuring principle** | Contacting transducer | Contacting transducer | Axlebox accelerometers |
| **Measurement of** | Single rail | Both rails simultaneously | Both rails simultaneously |
| **Requirements regarding train or vehicle** | None: portable system | Minimal wheel irregularities | Minimal wheel irregularities<br>Electronic tachometer<br>Good primary suspension: minimal friction elements |
| **Typical accuracy in 30-100mm wavelength range** | Better than 0.001mm RMS | Better than 0.010mm RMS | Better than 0.015mm RMS |
| **Computing requirements** | Laptop, 75MHz Pentium or better | Laptop or desktop, 75MHz Pentium or better | Desktop, 500MHz or better |
| **Software** | Proprietary, Windows based | Proprietary, Windows based | Proprietary, Windows based |
| **Data collection, signal processing & display [1]** | - Profile of one rail at 1mm or 2mm interval and 0.01 micron resolution<br>- Filtered profiles [2]<br>- RMS amplitudes in "block" or moving window [2]<br>- Peak-to-peak amplitudes in | - Profile of both rails at 2mm interval and 1 micron resolution<br>- Filtered profiles [2]<br>- RMS amplitudes in "block" or moving window [2]<br>- Peak-to-peak amplitudes in | - RMS amplitudes in "block" [3] |

| Feature | CAT | RCA | HSRCA |
|---|---|---|---|
| | block or moving window [2]<br><br>- Percentage exceedence [4]<br><br>- One-third octave band spectra | block or moving window [2]<br><br>- Percentage exceedence [4] | <br><br>- Percentage exceedence [4,5] |
| **Automatic detection of discrete irregularities (e.g. welds)** | No | No | Yes, ranked into up to 7 ranges of severity |
| **Annotation of records with features of line (bridges, etc.)** | No | Yes | Yes |
| **Typical uses** | - Corrugation surveys and troubleshooting<br><br>- Quality Assurance for grinding<br><br>- Accurate measurement of short lengths of track (2-5km/h)<br><br>- Measurements for acoustics work<br><br>- Verification and calibration of other equipment, e.g. RCA and HSRCA | - Corrugation surveys for metros or other relatively small railway systems<br><br>- Quality assurance for grinding<br><br>- Accurate measurement of moderate lengths of track | - Measurement of complete rail systems to assess grinding requirements |

**Notes:**

1. All software can export ASCII files of calculated data e.g. for post-processing with other software.
2. For wavelength ranges 10-30mm, 30-100mm, 100-300mm, 300-1000mm, 1000-3000mm, 30-300mm, 300-3000mm and 150-1500mm.
3. For up to 7 non-overlapping, user-specified wavelength ranges
4. The “percentage exceedence” is the percentage of the measured length over which a measurement of the profile exceeds a specified limit. The measurement can in principle be of any quantity e.g. raw or filtered profile, RMS or peak-to-peak average displacement in a moving window.
5. For the HSRCA, percentage exceedences can be calculated for up to seven specified amplitude limits.

# 8. About *RailMeasurement*

*RailMeasurement* is a professional engineering company with over 25 years experience in the development and supply of precision instruments for the railway industry.