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The Multiple Probe Array

by

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Some years ago, when the Audigage was widely used in England and abroad for the testing of rails, the B.R. Research Department was approached with the request to propose an improved method of rail testing. This seemed advisable because the Audigage, a resonant ultrasonic device, could not reliably detect the majority of rail flaws, in particular the defects in the dangerous zone around the bolt-holes at the rail ends. Because of this the Audigage, though efficient and quick when used on the plane sections of rail between the rail ends, had to be complemented by hand operated ultrasonic equipment to investigate the bolt-hole zones. Using the pulse echo method with this equipment, both 0° and angle probes had to be employed for the examination of rail ends, and recalibration was necessary after each probe change.

The B.R. Ultrasonic School at Derby gained considerable experience with the manual rail testing method, and developed remarkable skill in testing and teaching. Around 300 operators have been trained successfully at Derby. However, the time lost with the necessary exchange of probes and with recalibration between the tests made it clear that hand-testing was too slow for practical purposes. - Requires hands and knees testing - No test of rail between the joints.

It was therefore considered wise that in spite of the reliable results obtained, an alternative possibility should be found, which would combine the advantages of the two methods without entailing their shortcomings, the aim being to examine speedily and reliably both the rail end zones and the rail portions between them. (Just to indicate the magnitude of the problem: there are 23,600 rail miles on B.R. track, with 4 million bolted joints.)

British Railways also evaluated at that time the "Rail Testing Scooter" of Continental design.

Based on the pulse echo principle, and equipped with an acoustic monitor, the scooter system uses selectively a 0° compression-wave probe and a pair of divergent shear-wave angle probes. The monitor, the couplant supply, and the efficient design make the scooter a reliable rail testing tool under the conditions of Continental, continuously welded track for which it was, in fact, developed. On British Railways track, however, where 4,000,000 rail joints have to be taken into consideration, it was felt a disadvantage that the scooter was not capable of detecting the defects around the bolt-holes which are considered to be particularly dangerous. These zones had to be examined manually as before, and it soon became evident that the rail testing scooter of Continental design did not bring about a substantial saving in the testing time, nor did it represent the ideal solution to our problems.

It was, of course, known that a fully equipped rail testing coach was capable of detecting and evaluating all the commonly occurring rail flaws including cracks in the bolt-hole area, and that reliable results could be obtained at a remarkable speed. At that time, a rail testing coach was being developed, but this was a long term project, and the Research Department was expected to find a solution quickly because of the increasing numbers of rail failures.

Flaws detected by the 0° probe are not necessarily accessible to shear-wave probes while, on the other hand, the 0° probe can miss defects which are found by shear-wave probes. In order to detect, and evaluate, every flaw in a rail it is therefore necessary to use a 0° probe in conjunction with a number of shear-wave probes having different angles. This, however, entails a corresponding number of different time-base speeds. While it is possible to show echoes simultaneously which are obtained from a number of probes working in parallel, such a display on the flaw detector screen is not practicable because of the standing echo signal from the bottom of the rail, which is produced by the 0° probe, and this signal lies in the active portion of the trace for shear-wave probes; thus rendering the system unsuitable for monitoring.

Apart from this, the screen picture would be very difficult to interpret in that it would not be clear where the defect signals originate. Walking along the track on railway sleepers can be very tricky; it is quite impossible to walk safely on the track and observe at the same time the transient flaw signals presented on the flaw detector screen. For this reason it was thought that an acoustic monitor was essential. However, as explained above, it is not possible to use a common monitor with a system which combines a 0° probe with shear wave angle probes sharing the same time-base. It was therefore evident that the problem would have to be approached from a different angle. A period of research and experimental work followed in an attempt to build up a rail testing system around a common time-base. The "Multiple Probe Array" is the outcome of this attempt.

By using a probe arrangement where one central 0° probe was transmitting only, and pairs of angle probes, symmetrical in relation to the central probe, were receiving - whereby the active zones of the angle probes were allowed to overlap, - it was possible to scan the whole cross-section of the rail. The arrangement has to suit the specimen characteristics, and the number of shear wave probes and their angles, depend on requirements.

The first model developed for the scanning of the rail cross section had, at the extreme ends, a pair of 40° probes facing one another, to examine the lower zones from the bolt-hole downwards. A pair of 67° probes, mounted together with a second pair of 40° probes on a common block, were arranged about halfway between the outer probes and the central 0° probe. The 67° probes scanned the rail head portion, and the 40° probes scanned the bolt-hole area. The probes were fitted to the B.R. scooter in an articulated suspension.

During on-site tests, the B.R. scooter was found to be rather clumsy. The matter had to be given some further thought before a solution could be proposed. The outcome of additional research was the "Walking-stick System" with a modified probe array, 67 - 40 - 26 - 0 - 26 - 40 - 67° combining shear and longitudinal transducers within one common block.

When the walking stick is moved along the rail at walking speed and the function box is switched to "search" - this being the mode in which the multiple probe array scans the whole cross-section - and the customary coupling supply is used, the monitor will react as soon as a flaw echo is received. Small flaws are clearly detected because their two signals combine to produce a maximum amplitude when the path lengths of the signals reflected to the symmetrically opposing, respective, receiving probes, are equal. The 0° probe is then precisely above the flaw in the rail. This increase in amplitude, brought about by the additive interference, greatly increases the signal-to-noise ratio and a very accurate indication of the location of a defect in the longitudinal plane is possible. The operator, warned by the monitor signal, can immediately interrupt his forward scanning, to investigate the zone where the monitor signal was given, and evaluate the cause. The function box, developed especially for this purpose, enables the operator to use every probe in the array individually, in the transmit/receive mode.

The time-base, and the delay, are automatically adjusted when selecting the probes. The flaws are therefore shown on the screen in their relative depth, with the running surface of the rail as a datum. The common time-base, and the monitor, used in conjunction with the necessary number of angle probes, allow the entire cross-section of the rail to be scanned reliably and swiftly. There are no probe changes or recalibration to slow down the work, and, as a result of using a combination of different angle probes, there is no danger of rail defects being left undetected when scanning the rail from the running surface.

It is virtually impossible to watch out for flaw indications on the screen while walking along the track. But this is not even asked of the operator. All he has to do is to cast an occasional glance on the screen, to satisfy himself that the system is operational, and to listen for any signal given by the monitor. It is therefore immaterial whether or not the distance between the flaw and the running surface is given, by the signal, true to proportion. So long as the signals received lie within the gated portion of the time-base, there is no need for a proportional display of the distance of the flaw under the running surface.

One of the greatest difficulties was the impedance matching of these numerous angle probes, including the design of the function box with its associated circuitry, because it was not permitted to make any alteration to the flaw detector itself, except for the fitting of a multiple pin socket. The pre-sets for time-base and delay, and all probe switching and matching had to be accommodated inside the function box. Among other problems, crosstalk had to be eliminated. However, the teething troubles were eventually overcome, and the walking stick is now used very successfully on all B.R. Regions and for the detection of all known flaws. There are more than 70 units in service, and more are being built, so that in the near future the number of walking sticks used on B.R. will be well over 100.

The merits of the Multiple Probe Array are by no means limited to its advantages for rail testing. Already the array has been acclaimed as a valuable aid when testing cold-rolled steel girders. The probe system detects flaws reliably which are known to elude the conventional methods.

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