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Technique used to assess allowable speed of ultrasonic rail testing

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Abstract

The results of investigating the parameters of ultrasonic signals when increasing rail testing speed presented. Signals from rail bolt holes were selected as test reflectors. It is shown that the holes closest to the rail joints are not sounded fully, and signals due to them cannot be used as test reflectors. For a full assessment of the deterioration of the quality of nondestructive testing of rails with an increase in the scanning speed, it is proposed to use the integral parameter of the reflector being analyzed. A noticeable decrease in this parameter at high speeds requires a compromise decision when choosing between performance and quality of rail inspection. The proposed technique can be used to assess the efficiency of operating and newly created flaw detection systems.

Keywords: ultrasound, flaw detection, rails, high-speed testing, B-scan, signal parameters, integral parameter

1 Introduction

High-speed railways flaw detection system (FDS), mainly based on ultrasonic (US) non-destructive testing methods, is a probabilistic diagnostic method that is difficult to verify. On the one part, they claim that with the contact input of ultrasonic vibrations, an increase in control speeds above 60 km/h leads to a sharp decrease in the reliability of control [1, 2, 3], on the other part, scanning speeds up to 140 km/h are declared [4].

Creation and operation a test section of the track with rated characteristics of the defect models, which allows arranging safe test runs of a flaw detector car at high speeds, is a very expensive and not always reasonable project. Such a check does not allow taking into account the specifics of the state of the rails from the missed tonnage and load density of the track. Defect models can only approximately reproduce the reflective properties of actual defects. Current speed limit and short length of the test sections of the track do not allow checking the performance of flaw detection systems at speeds above 40-60 km/h.

The permissible inspection speed, subject to the specified probability of detecting defects, depends on the functionality and specifications of the flaw detection complex, as well as the state of the rails on the controlled section of the track.

The work is aimed to develop a method would allow to objectively determine the allowable scanning speed (working control speed) of a FDS on sections of a rail track of different traffic flow. Without denying the need for regular inspection of FDS in specially prepared areas, this report proposes an express method for estimating their performance, providing an inspection directly during the working passage of the FDS.

The influence of high testing speeds on the characteristics of signals from defects in rails should be established by echo signals from typical reflectors with known parameters, regularly recorded on real ultrasonic flaw signal patterns. Holes of bolted joints of rails with a diameter of 36 mm can be chosen as reflectors.

The method does not require additional time and material costs (except for an additional function in the FDS software). The proposed method can be used in the course of implementation of new FDS, and regular assessment of the performance of the operating FDS. It can also be used to choose acceptable testing speeds in areas of different traffic flow.

2 Research Methodology

Even on a jointless rail track, there are a sufficient number of bolt holes in equalizing spans, railroad switches and so on.

The signals from bolt holes have the following properties: the zone of occurrence of reflecting points from the wall of holes (105 mm) is in the zone of formation of many real defects in the web and head (with a single reflection); amplitudes and conditional sizes of signals from holes and defects are comparable or close.

On continuous sections of the track, on average, every 800 m, to compensate for thermal expansion of the bar, they provide from two to four pairs of discharge links connected by bolted joints. For example, when the flaw detection system is moving at a speed of 30 m/s (108 km/h), signals from 12 to 20 holes on each track will be recorded every 27 seconds.

During the movement of the search system along the rail head running surface, the side walls of the holes are successively sounded by transverse ultrasonic vibrations at the input angles $\alpha = \pm 42°$ from both sides (these angles are taken equal to ±45° or ±35° [2, 3, 5]). Direct piezoelectric transducers (PET) introduce longitudinal ultrasonic vibrations normally ($\alpha = 0°$) to the scanning surface (Fig.1a).

On the flaw signal pattern (in the form of B-scan [3, 6, 7]), two inclined lines (packs) of signals are formed from each hole with a conditional length (location zone) along the length of the rail ΔL (Fig.1b) and one arc-shaped pack (Fig.1c).

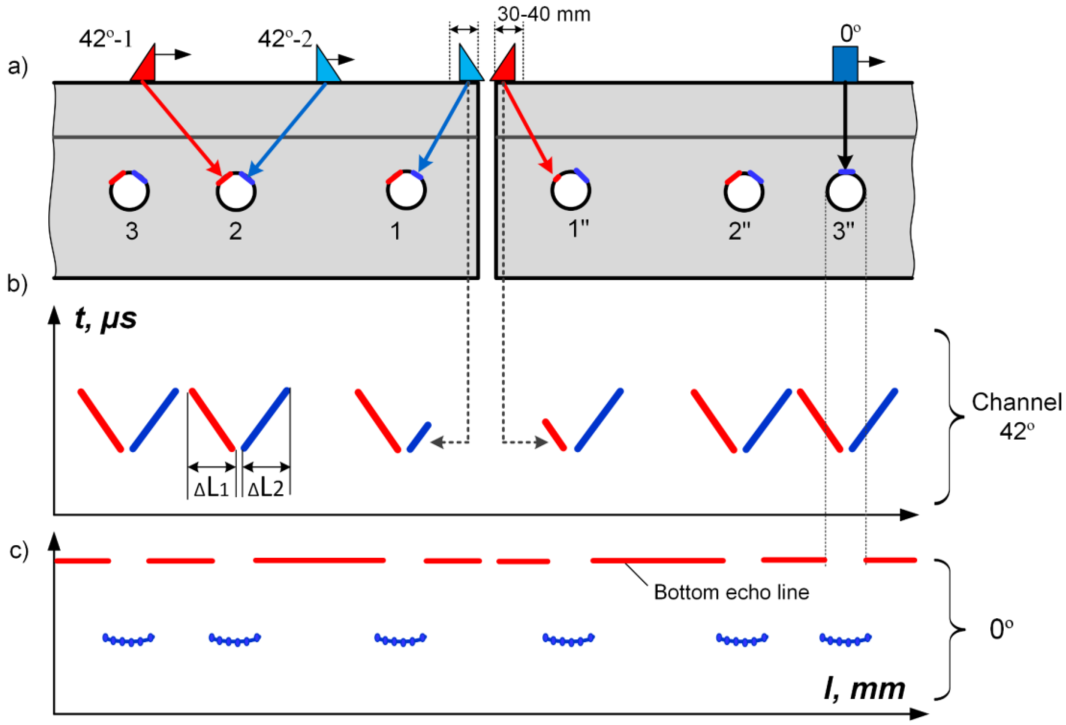

Figure 1: Formation of signals in the area of the bolted joint: a - incomplete sounding of the first holes from the side of the ends of the rails; b – in PET channels α = ± 42°; c – direct PET α = 0°[7].

Due to the proximity of the first holes to the ends of the joined rails, the location zone of these holes from the side of the ends is only 30-40 mm long. The signal packs are formed from these holes with much (up to three times) smaller sizes *ΔL* (Fig.1b). In addition, at high inspection speeds, due to the dynamic effects of joint irregularities on PET blocks, the first holes are sounded worse. Thus, when using signals from the bolt holes as test reflectors, one should exclude the first holes from the analysis, and take into account the parameters of ultrasonic signals only from the second and third holes.

3 Results

Fig.2 shows the results of the analysis of the detection of bolt holes by PET with an angle of 42° at inspection speeds 30 - 100 km/h for two different FDSs. The quality of ultrasonic testing by both FDSs is much lower (up to 20%) with an increase in the speed *V*.

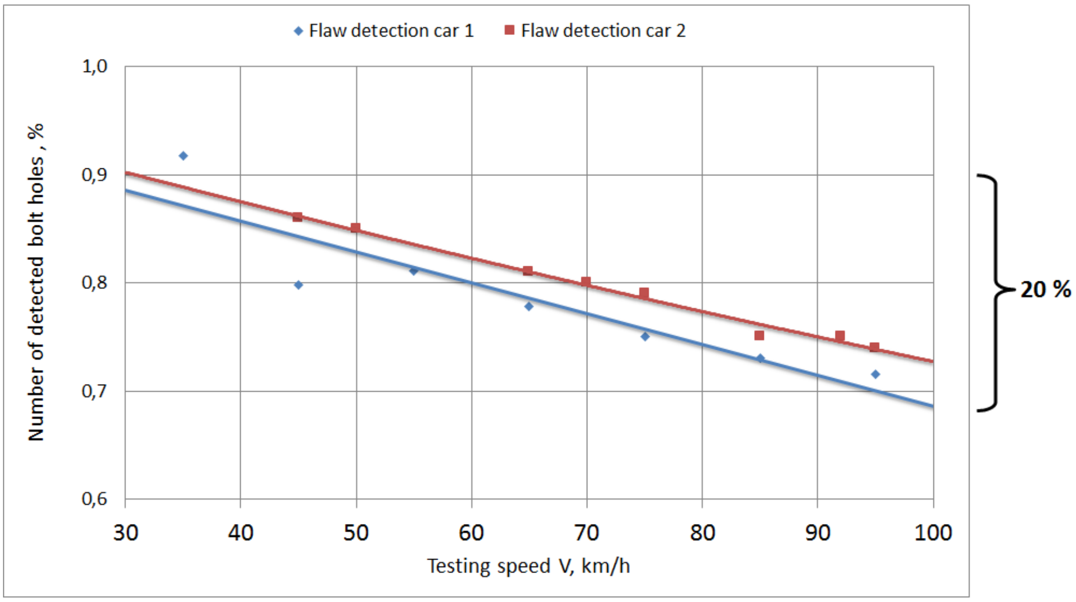

Figure 2: Reduction in the number (in %) of bolt holes with an increase in the speed V.

The conditional length ΔL is a main measurable parameter of the reflector. This value for a given reflector must be constant. However, as shown in [8], at significant the V, due to a noticeable shift of the PET during the propagation of ultrasonic vibrations to the defect and back, the ΔL can be even lower, the greater the V. The compression of the conditional length ΔL_{dyn} of a defect from the speed V compared with the values obtained under stationary conditions (ΔL_{st}) is about 6% at $V = 30$ km/h, and almost 20% at 100 km/h [9].

Studies on 430 bolted joints show that with an increase in the scanning speed from 30 to 100 km/h, the conditional length ΔL from the second and third bolt holes is reduced by 30% (Fig.3). This is more than the theoretical values by 5 - 10% and is related to the manifestation of several negative factors in real control conditions (the instability of the acoustic contact).

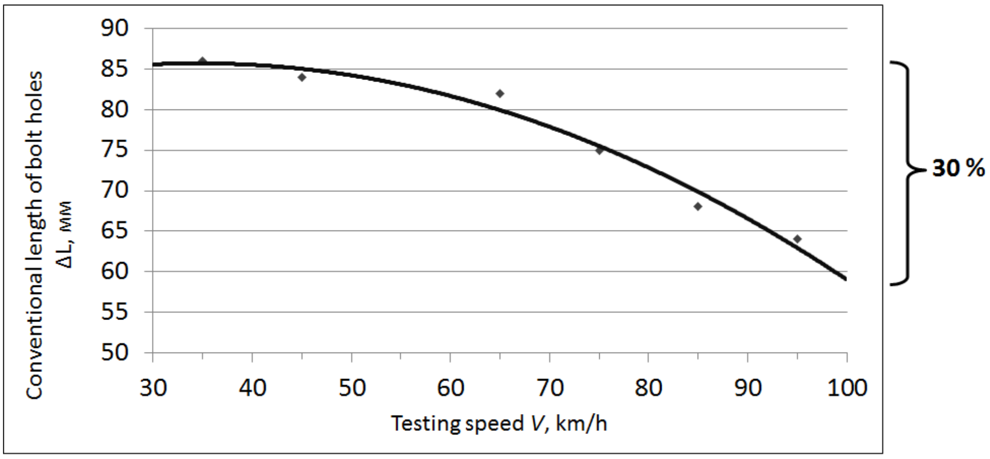

Figure 3: Dependence of the ΔL of signals from bolt holes on the speed V.

For a more complete estimation of the recorded ultrasonic signals, similar to [10], we use the generalizing (integral) parameter K_{int} of the analyzed reflector (Fig.4).

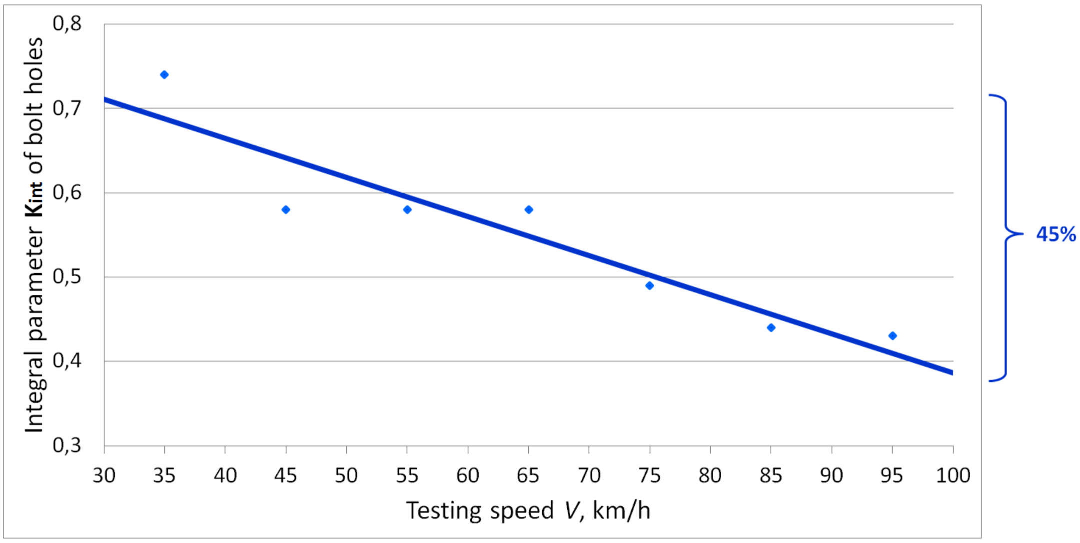

Figure 4: Change in the parameter K_{int} of signals from bolt holes.

The parameter K_{int} is a linear combination of individual indicators in n flaw detection channels of the FDS that recorded signals from the reflector:

$$K_{int} = a_1K_1 + a_2K_2 + ... + a_nK_n, \quad (1)$$

where $0 < a_n < 1$ – weight coefficient of the channel n.

The parameter K_n in a separate channel is determined by the equation:

$$K_n = l\,(U_1 + U_2 + ...\,U_i)\,/\,m_n, \quad (2)$$

where l is the scanning step along the length of the rail, U_i – the amplitude of i-signal of the packs, m_n - the maximum possible signal from the reflector to normalize the K_n $(0 < K_n < 1)$.

The parameter K_{int} allows estimating one of the signal parameters, and integrally takes into account conditional length ΔL and amplitude U_i of all echo signals received from the reflector simultaneously through all channels of the flaw detector.

4 Conclusions and Contributions

Comparison of fig. 3-4 shows that with an increase in speed (30 - 100 km/h), the K_{int} parameter for the signals from the holes drops more (by 45%) compared to the conventional length ΔL (by 30%). This is a certification of a noticeable reduction in the number of recorded echo signals, and a noticeable decrease in their amplitudes.

The K_{int} of the analyzed reflector [10] is the most meaningful parameter. Therefore, the assessment of the quality of the US testing of the rail at different inspection speeds shall be performed using it.

The method can be implemented according to the algorithm: once K_{int} from 20-30 bolt holes is determined, the values of the averaged parameter K_{av} are calculated in every subrange ΔV (5-10 km/h each). Based on the obtained values of K_{av}, a nomogram for the dependence of the average estimate of the FDS performance on V is constructed (Fig.5). On the same nomogram, a line of the threshold value of the K_{thr} estimate, acceptable for a given section of the track, is plotted. At the point of intersection of K_{av} with the threshold level K_{thr} (for FDS *B* in Fig.5), the limiting speed V_{lim} of control of this section of the track is determined. The track is checked at an operating speed not exceeding V_{lim}.

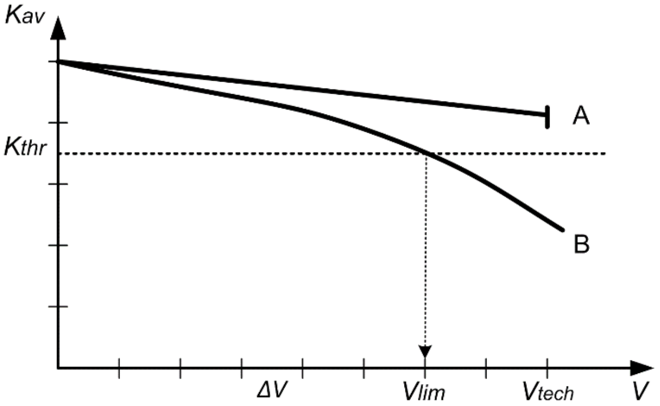

Figure 5: Nomogram for determining the allowable control speed for FDC (*A* and *B*). For FDC *B*, section testing is possible at speeds up to V_{lim}.

Taking into account the improved design of the testing system, the K_{av} curve for FDS *A* (Fig.5) does not intersect with the threshold level. In this case, the ultrasonic flaw detection of this section can be carried out at the maximum speed V_{tech}.

Depending on the state of the track, the same FDS can have a different limiting control speed V_{lim}. The proposed method makes it possible to estimate the performance of high-speed FDS directly in the course of a working passage along the operated track without special test sections of the track. The technique provides the choice of optimal control speeds depending on the actual state of the railway track. Due to the periodic testing of the FDS performance in real conditions, the certainty and reliability of detecting defects in the rails at high scanning speeds is increased.

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