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**ULTRASONIC DETECTION OF RAILROAD AXLE CRACKS UNDER WHEEL HUB WITH LONGITUDINAL WAVES**

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**1. Introduction**

In railroad transport, fatigue cracking of railroad axles are one of the major source of railroad accidents. To detect cracks emerging on surface of an axle ultrasonic technique (UT) is widely used. Axles are usually tested during periodic inspection of wheelsets. Dangerous fatigue cracks often emerge on the axle wheel-seat. These cracks are covered with a wheel hub press fitted on the axle. Schema of UT detection of such cracks with shear and longitudinal waves is shown on Fig. 1. Depending on axle and wheel geometry, specific angle probeheads for ultrasonic shear (SV) and longitudinal (L) waves are used in tests. To detect a crack with shear wave it is necessary to couple the probeheads to the cylindrical part of the axle, between wheel-seats. Such test can be performed on the wheelset dismantled from the bogie. Testing with longitudinal wave requires access to the flat, front axle face what enables inspection of axles in cars, on track (Fig. 1.).

In both cases, ultrasonic pulse reflects on a corner formed by cylindrical surface of the axle and surface of the crack. When detecting crack situated under the wheel hub, echo amplitude can be affected (reduced) by the contact between axle and wheel press fitted on axle. Amplitude of the ultrasonic wave reflection on the axle-seat – wheel hub boundary is lower comparing to reflection on steel – air boundary. Value of reflection coefficient depends on contacting surfaces conditions like roughness, presence (or not) of the grease and pressure. The influence of above factors on UT detection of such cracks with shear waves is described in details in [1]. Paper describes the influence of wheel-axle contact on UT detection of fatigue crack detected with longitudinal wave launched form the axle face.

**2. Experiment**

Fig. 2 present the experiment setup. Two steel samples, made of carbon steel with surface roughness the same as in axle and wheel bore ( $R_a = 1,6 \mu m$ ), were pressed with force  $F$ . Three angle ultrasonic probes for 3 MHz longitudinal wave, refraction angle  $27^\circ$ , were fixed to the samples.

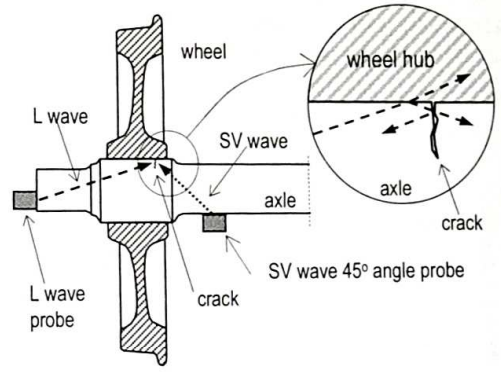


Fig. 1. Methods of ultrasonic crack detection in railroad axle with shear and longitudinal waves.

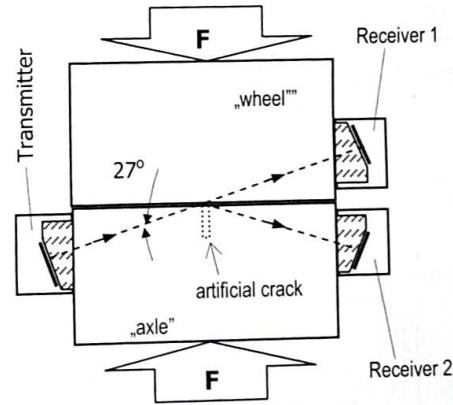


Fig. 2. Setup to evaluate coefficients of reflection and transmission for longitudinal wave and flaw echo amplitude on pressure between contacting surfaces.



The first readings were taken on flat samples. Signals received by two receiving probes allowed to monitor reflection and transmission coefficient changes with contact pressure.

Next measurements were performed with transmitting probe operating in echo mode, on samples with artificial cracks (dotted line on Fig 2) of various depths. These tests allowed to monitor the dependence of flaw echo amplitude changes on pressure between samples. To imitate real conditions, tests were performed for "dry" contacting surfaces and for surfaces covered with grease.

### 3. Results

Figs. 3 and 4 present dependence of artificial flaw echo amplitude on contact pressure between samples. Fig. 3 for samples with grease between samples, Fig.4 – without any grease (dry contact).

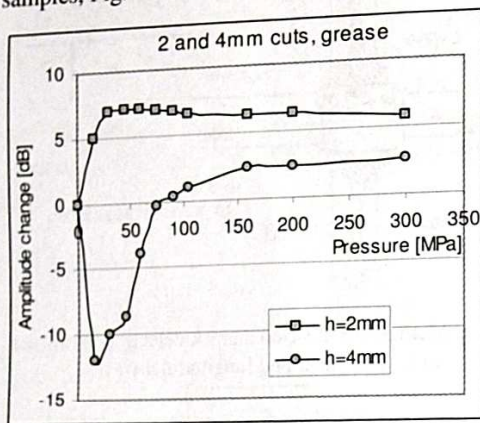


Fig. 3. 2 and 4 mm deep cut echo dependence on contact pressure. Grease between samples.

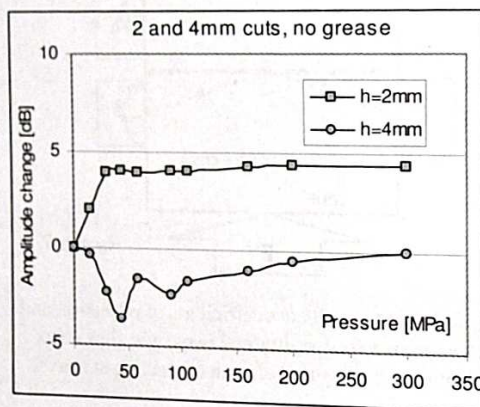


Fig. 4. 2 and 4 mm deep cut echo dependence on contact pressure. No grease between samples

It can be seen that for both, "dry" and "grease" contact, echo amplitude depends on pressure between samples. As expected higher amplitude changes with pressure are observed for samples covered with grease. Amplitude changes also

depend on artificial crack depths. For 4 mm cut (cut depth equal to about 2 wavelength) echo amplitude drops for contact pressure up to 75 MPa and 300 MPa for "grease" and "dry" conditions respectively. Significant amplitude drop, equal to about 12dB, was observed for "grease" condition and low pressure. However, for 2 mm cut (depth comparable to the wavelength) echo amplitude rises with contact pressure. For "grease" conditions this amplitude increase reaches 7.5 dB for pressure equal to 25 MPa only.

### 4. Conclusions

Results of presented experiment show that echo amplitude for crack situated under the wheel hub and detected with longitudinal wave launched from the axle face, depends on numerous factors. They are: pressure between axle seat and wheel-hub (which can vary from point to point [2]), conditions (dry, grease) and also crack depth. Echo amplitude for dangerous cracks, depth higher than a wavelength, can be reduced by factor 4. Results show that calibration of ultrasonic equipment on artificial flaws cut on free axle surface (without contact with wheel hub) can lead to errors. Sensitivity of ultrasonic test determined in such a way will not ensure detection of cracks, of the same depths in a wheelsets.

One more factor reducing fatigue crack echo amplitude is lower than 100% reflection coefficient of longitudinal wave on crack surface. Railroad axle in a car is subjected to bending. Fatigue crack can be opened or closed depending on position of a wheelset in relation to load direction. Measurements performed in the first experiment (on flat samples) showed that, for L wave and 27° incidence angle, echo amplitude drop resulting from contact pressure can reach 10 dB. Both effects, pressure on axle-wheel boundary and compressive stress on crack surfaces, can sum up. In result echo amplitude of a real crack in the axle can be reduced by factor 14 comparing to echo amplitude measured on the same depth reflector, on free axle.

### References

- [1] Kazunari Makino, Shiro Biwa, Influence of axle-wheel interface on ultrasonic testing of fatigue cracks in wheelset. *Ultrasonics*, 53, 2013, pp.239-248].
- [2] M.B. Marshall, R.Lewis, R.S. Dwyer-Joyce F. Demilly, Y. Flament, Ultrasonic Characterisation of Wheel Hub/Axle Interference Fit Pressures, *Journal of Rail and Rapid Transit*, Vol. 225, 2011, pp 287-298