DEFECT EVALUATION IN RAILWAY WHEELSETS

Seok Jin KWON
Senior Researcher
Railway System Research Dept.
Korea Railroad Research Institute
360-1, Woram-dong, Uiwang-city, Kyonggi-do , 437-757, Korea
Fax: 82-31-460-5249
E-mail: sjkwon@krri.re.kr

Dong Hyong LEE
Senior Researcher
Railway System Research Dept.
Korea Railroad Research Institute
360-1, Woram-dong, Uiwang-city, Kyonggi-do , 437-757, Korea
Fax: 82-31-460-5246
E-mail: dhlee@krri.re.kr

Jung Won SEO
Senior Researcher
Railway System Research Dept.
Korea Railroad Research Institute
360-1, Woram-dong, Uiwang-city, Kyonggi-do , 437-757, Korea
Fax: 82-31-460-5210
E-mail: jwseo@krri.re.kr

Won Hee You
Director
Railway System Research Dept.
Korea Railroad Research Institute
360-1, Woram-dong, Uiwang-city, Kyonggi-do , 437-757, Korea
Fax: 82-31-460-5200
E-mail: whyou@krri.re.kr

Abstract The wheelsets are one of most important component: damages in wheel tread and press fitted axle are a significant cost for railway industry. Since failure in railway wheelset can cause a disaster, regular inspection of defects in wheels and axles are mandatory. Ultrasonic testing, acoustic emission and eddy current testing method and so on regularly check railway wheelset in service. However, it is difficult to use this method because of its high viscosity and because its sensitivity is affected by temperature. Also, due to noise echoes it is difficult to detect defects initiation clearly with ultrasonic testing. It is necessary to develop a non-destructive technique that is superior to conventional NDT techniques in order to ensure the safety of railway wheelset. In the present paper, the new NDT technique is applied to the detection of surface defects for railway wheelset. To detect the defects for railway wheelset, the sensor for defect detection is optimized and the tests are carried out with respect to surface and internal defects each other. The results show that the surface crack depth of 1.5 mm in press fitted axle and internal crack in wheel could be detected by using the new method. The ICFPD method is useful to detect the defect that initiated in the tread of railway wheelset.

Key Words : Railway wheel, Axle, Surface damage, Internal defects

1. INTRODUCTION

The fatigue cracks are initiated in railway wheel tread which suffer from rolling contact fatigue damage. Three different mode of fatigue initiation and crack growth in railway wheels are identified, such as the ratcheting, macroscopic defects and flats [1]. Fatigue failures are much more than violent than wear and may cause a part of the wheel to break off, leading to damage to the rail and to train suspensions and bearings and may even cause derailment. Although the wheelset materials are considerably improved, the damages of the railway wheelset have continually appeared as can seen from Fig. 1. If the inspection interval of the wheel could be omitted by high quality NDI, the maintenance costs for railway vehicle wheelset would decrease significantly. We need to confirm that any cracks overlooked by non-destructive tests in the wheel inspection do not propagate before the next general inspection, when magnetic particle inspection is performed. During the last few years, the NDT of wheelset for railway vehicles has been extensively studied, and many research results have been published. M. Saka et al. [2] used a Direct Current Potential Drop technique to study the nondestructive sizing of three-dimensional surface cracks in wheelset. J.Yohso et al. [3] reported on ultrasonic testing using a grazing SH-wave for detecting cracks in wheelset axles of railway vehicles. P. Rainer et al. [4] developed the NDT for the in-service inspection of railway wheel and eddy current application focused mainly on the detection of head check defects occurring at the gauge of the rail studied.

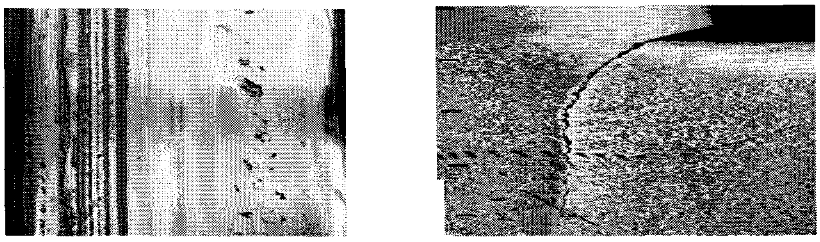

Fig. 1 Damage of railway wheel tread(left) and axle(right)

Recently, the railway wheelset in service are regularly checked by ultrasonic testing and eddy current inspection. However, the ultrasonic testing method is difficult to detect the crack initiation clearly due to the noise echoes [3]. Therefore, it is necessary to develop a non-destructive technique that is superior to conventional NDT techniques in order to ensure the safety of high-speed wheelset. The induced current focusing potential drop (ICFPD) technique is a new non-destructive testing technique that can detect cracks in railway wheels by applying on electro-magnetic field and potential measurement [5]. In the present paper, the application of ICFPD method to the detection of artificial crack for railway wheelset is investigated.

2. APPLICATION OF ICFPD

Fig.2 shows the principal of the ICFPD technique. When a current is applied to an induction wire, an electromagnetic field is induced in the area surrounding the induction wire. If alternating current flows in an induction wire placed near a conductive metal, the electromagnetic field induces a current in the conductive metal. Accordingly, the potential drop associated with the induced current can be measured [6-7]. Because it is same as Alternating Current Potential Drop (ACPD) technique, induced current also flows preferentially on the surface layer of metals (or metal specimens) due to the skin effect.

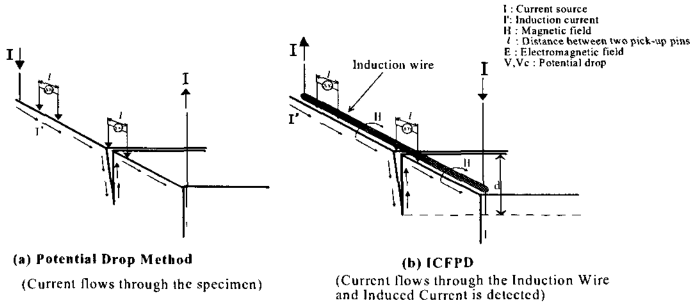

Fig. 2 Principal of the ICFPD method

3. EXPERIMENTAL PROCEDURES

3.1 Test specimen

The railway wheel used for this test was the rolling contact fatigue specimen and had artificial flaws 0.5, 1.0, 1.5, and 2.0 mm depth. The test conditions are shown in Table 1 Sensors with 10 mm pick-up distance and induction wires 40 mm length can detect cracks at a long distance.

Table 1 Test conditions

Frequency (kHz)	Current (A)	Gain (dB)
0.3, 3	2.0	50, 70, 90
ICFPD Sensor	Lengths of induction wires (l_w) = 40 mm	
	Distance between pick-up pins = 10 mm	

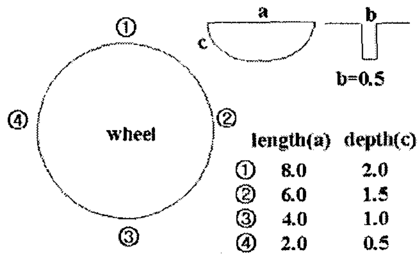

Fig. 3 Artificial crack sizes for test

Fig. 3 shows the artificial crack size used in the tests. The tests are carried out with respect to 4 surface defects each other. The geometries of the surface defects are used semi-elliptic crack, which initiated in railway wheel.

3.2 Measuring system

Fig.4 shows the measuring system used in the tests. The measuring system consists of the measuring sensor, a jig for controlling the contact force between the pick-up pins and the rail, a device for measuring potential drops. The measuring system for crack detection for railway wheel can easily measure azimuthal direction of the crack by installing casters underneath the railway wheel and indicating the rotation angle on an attached graduator. Also, a measuring system was used to move the pick-up pins in the axial direction and constantly sustain the contact force between the pick-up pins and the wheel tread. Using ICFPD for crack detection in railway wheel was performed in the azimuthally directions.

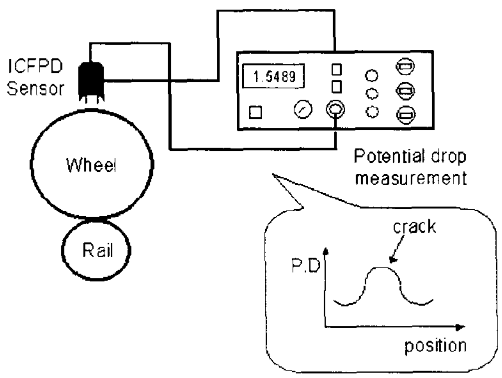

Fig. 4 Schematic diagram of measuring system

4. EXPERIMENTAL RESULTS & DISCUSSIONS

4.1 RAILWAY WHEEL

The variations of potential drops in accordance with the difference of crack depth with respect to the surface defect of wheel are shown in Fig. 5 and Fig. 6. The cracks in the railway wheel were inspected in the azimuthal direction. As can be seen from Fig. 5, the potential drop for the sensor with a 10 mm distance between pick-up pins increased remarkably at 0 mm distance which defect is existed and decreased at other locations. It is thought that pick-up pins distance close together can scan regions of high current density, which is the sensor with pick-up pins close together can measure the potential drops more sensitivity. It was shown the potential drop increased remarkably at the crack location. It is clear, therefore, that cracks can be detected at crack depth of 0.5mm. In case of ICFPD technique, the variations of potential drops without defect are not appeared and the variations of potential drops with defect are considerably occurred as can be seen from Fig. 6.

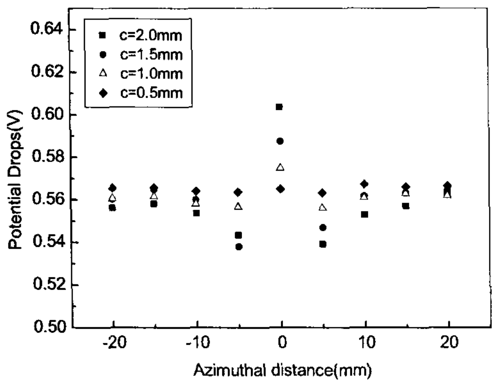

Fig. 5 Variations of P.D at pick up pin=10mm

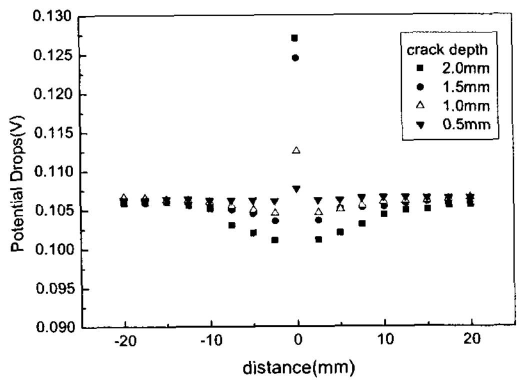

Fig. 6 Variations of P.D at pick up pin=5mm

The variation of potential drop by pick up interval 5 mm is shown in Fig. 6. As can be seen from Fig. 5 and Fig. 6, 0.5 mm defect can be detected. As can be seen from Fig. 6, crack detection with a pick up interval 5 mm demonstrated good results. Totally, Induced current in surface of a specimen flows in the opposite direction of the current in an induction wire. Lorenz forces create on attraction force because the induced currents that are distributed underneath the induction wire all flow in the same direction. As shown in Fig. 6, a part of the induced current around the induction wire is attracted to the region of high current density and the current density around the induction wire decreases. According to this mechanism, it is suggested that the potential drops decrease as the induction wire is close to the discontinuity.

As mentioned in previous section, if the NDT of the wheel can detect definely smaller crack, the maintenance costs for railway vehicle wheelset will decrease significantly.

4.2 RAILWAY AXLE

In order to verify the effects on the section area and crack, the axial and azimuthal directions were checked. The variation of potential drop in accordance with the frequency of the source current with respect to the 2 mm deep crack is shown in Fig. 7. The cracks in the railway axle without wheel were inspected in the axial direction. As can be seen from Fig. 8, the potential drop for the sensor with a 5 mm distance between pick-up pins decreased at a distance from D= 2 mm to 3 mm, where D is the distance from the crack to the pick-up pins. The variation of potential drops at distance greater than D=5 mm was not significant, even though the test frequency was changed to a higher frequency band. However, the potential drops for the sensor with a distance between pick-up pins of 3 mm decreased at locations from D= 1 mm to 3 or 4 mm and gradually saturated at locations greater than D=10 mm. It is thought that pick-up pins distance close together can scan regions of high current density, which is the sensor with pick-up pins close together can measure the potential drops more sensitivity. As can be seen from Fig. 7, crack detection with a 3 kHz current source demonstrated good results. It was shown the potential drop decreased remarkably at a distance of 2mm from the crack location and was saturated at distance greater than 10mm. It is clear, therefore, that cracks can be detected at a distance of 10mm. As can be seen from Fig. 8 an interesting phenomenon with downward curves on some intervals, has occurred. The reason can be explained by the edge effects due to Lorenz forces [7]. Due to skin effect induced current easily flows on the surface layer of the specimens. Especially in case of ferromagnetic material, the effect is remarkable.

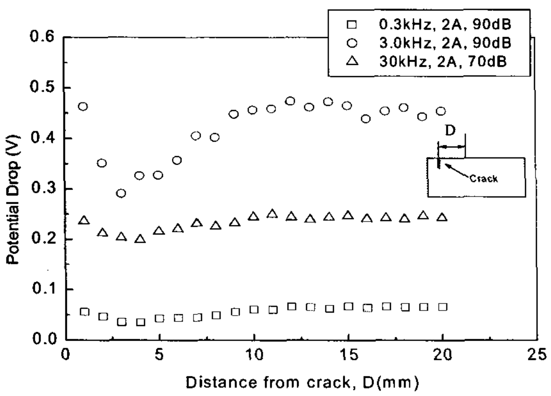

Fig. 7 Variation of potential drop without wheel

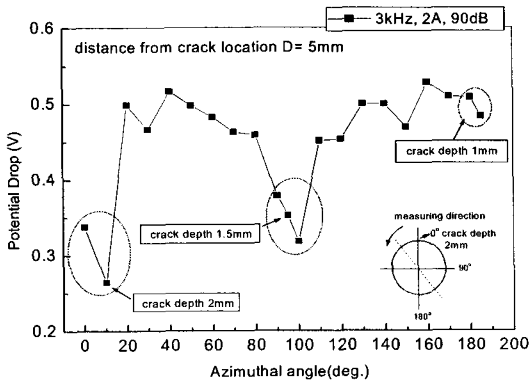

Fig. 8 Variation of potential drop without removing wheel

If a discontinuous part (or crack) exists in a specimen, the induced current loses one's way and constitutes a region of high current density around the edge of the discontinuous part. In case of D=1.mm or D=2 mm, it is thought that high potential drops are detected due to the region of high current density around the edge. Induced current in surface of a specimen flows in the opposite direction of the current in an induction wire. Lorenz forces create on attraction force because the induced currents that are distributed underneath the induction wire all flow in the same direction. A part of the induced current around the induction wire is attracted to the region of high current density and the current density around the induction wire decreases. According to this mechanism, it is suggested that the potential drops decrease as the induction wire is close to the discontinuity.

As mentioned in previous section, if the NDT of the axle can be done without removing the press fit wheel, the maintenance costs for railway vehicle wheelset will decrease significantly. Fig.8 show the variation of the potential drop without removing the wheel from the railway axle at D=5 mm. In Fig. 8, it can be seen that a variation of the potential drop occurred at the location of the 1.5 and 2.0 mm depth cracks compared to positions in the specimen without cracks. Moreover, there was a distinct variation of potential drop that occurred with respect to the 2 mm deep crack at D= 10 mm. The results show that for the railway axle with a press fit railway wheel, 1.5~2.0 mm deep crack can be definitely detected at a distance of 5 mm from the crack. Furthermore, this result shows that the accuracy of the crack detection of the newly proposed ICFPD technique is superior to UT, which could only detect the 3 mm deep crack. As can be seen from Fig.6 and Fig. 8, it is evident that the newly proposed ICFPD technique can detect cracks in an axle without removing the wheels.

5. CONCLUSION

The ICFPD technique used in this study can detect cracks in railway wheels and axle. From the above results, the ICFPD technique is useful for detecting the cracks that start in railway wheels. The newly designed ICFPD technique can detect cracks 1mm and 2mm deep in a railway wheel and axle.

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