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SUPPLEMENTARY MAGNETIC TESTS FOR RAILWAY WHEEL SETS

Summary: During manufacturing process the wheel set is subjected to many different flaw detection methods; however, these methods are not sufficient while the wheel set is in service. The paper presents an example of monitoring of magnetic parameters changes of wheel set rolling surface (changes result from material degradation due to material fatigue).

DODATKOWE BADANIA MAGNETYCZNE DLA KOLEJOWEGO ZESTAWU KOŁOWEGO

Streszczenie: W ramach procesu produkcyjnego kolejowego zestawu kołowego stosowanych jest wiele metod defektoskopowych. Metody te nie są wystarczające w badaniach eksploatacyjnych i naprawach zestawu kołowego. W artykule przedstawiono monitoring zmian parametrów magnetycznych powierzchni tocznej koła od degradacji materiału wywołanej obciążeniami zmęczeniowymi.

1. INTRODUCTION

So far testing the wheels during the manufacturing process has been done by X-ray (RT), ultrasound (UT), eddy currents (ET) and magnetic (MT) . Rockwell or Brinell hardness tests are also very important. During rail vehicle operation the basic methods of diagnosing the wheels are ultrasound and eddy current methods. However, even the uses of such sophisticated inspection processes do not ensure full reliability of the bogie and undercarriage and the wheelset in particular, as documented in analysis of known cases of railway failures. The method presented in the paper asks for a further step in the railway wheel sets diagnostics. This method is tested in the PKP rolling stock maintenance plants. Proposed tests are based on the ferromagnetic properties of the steels as well as on magneto-mechanical effects and magnetic processes occurring in the material and caused by degradation due to fatigue. This new diagnostics is a distinct valuable supplement of the wheel inspection and especially of the wheel rolling surface tests. Additional tests based on the measurement of the tangential component of the magnetic field intensity at the rolling surface detect harmful internal stresses and their development with time as well as change in the physical parameters of the material due to improper operation.

2. WHEEL SET DIAGNOSTICS DURING MANUFACTURING PROCESS

The complex process of controlling wheel sets, wheel centers, monobloc wheels and wheel tires has tremendously limited the probability of failure of the used components. Different diagnostic methods are usually applied [1]. They are indicated in Tab.1.

Tab.1

Wheel set components testing during manufacturing process

tested element	Testing method					
	RT	hardness tests	geometry measurements	UT	MT	ET
wheel tire	X	X	X	X	X	
wheel centres	X	X	X	X	X	
monobloc wheel	X	X	X	X	X	
wheel set	X	X	X	X	X	

These methods result in eliminating pieces with material discontinuities (flaws), microstructure changes and internal stresses defined by change in wheel or wheel centre material hardness. UT and RT allow to inspect the bulk material, while by MT a check of the surface and subsurface layers is only performed.

3. WHEEL SET OPERATIONAL DIAGNOSTICS

Wheel set operational diagnostics (for high speed trains) is mostly focused on cyclic inspections, when the rolling surface geometry is assessed. Rolling surface wear shows how wheel and track interact. During inspection or repair cycles ET and UT are mostly used for wheel set testing (wheel sets either remain in place or are dismantled) – Tab.2.

Tab.2

Wheel set components operational diagnostics

tested element	Testing method					
	RT	hardness tests	geometry measurements	UT	MT	ET
wheel			X	X		X
wheelset			X	X		X

Ultrasonic waves (UT) penetrate the wheel tire material and inspect a depth range of 10 mm and deeper, while eddy currents tests (EC) can cover the 10 mm thick layer beginning at the surface. Eddy current probe frequencies are selected so that the tests will detect any material discontinuity rather than structural changes. Such changes are not “visible” in the frequency range under consideration.

4. FATIGUE PROCESSES DETECTION

When the wheel set is in operation, changes emerge in the rolling surface upper layer. These are structural changes as well as magnetic and mechanical parameter changes. These can indicate the fatigue processes which accumulate in the wheel set's rolling surface. The common diagnostics procedures are not sensitive to the material structure. The wheel set materials were investigated with the help of BEMI (Barkhausen Noise and Eddy Current Microscope) in the Fraunhofer Institute (Saabrücken, Germany). Detection of contact load induced changes in the material structure (Fig.1) were detected by the implemented eddy current module for frequencies greater than 1,5 MHz [3,4] (Fig.2).

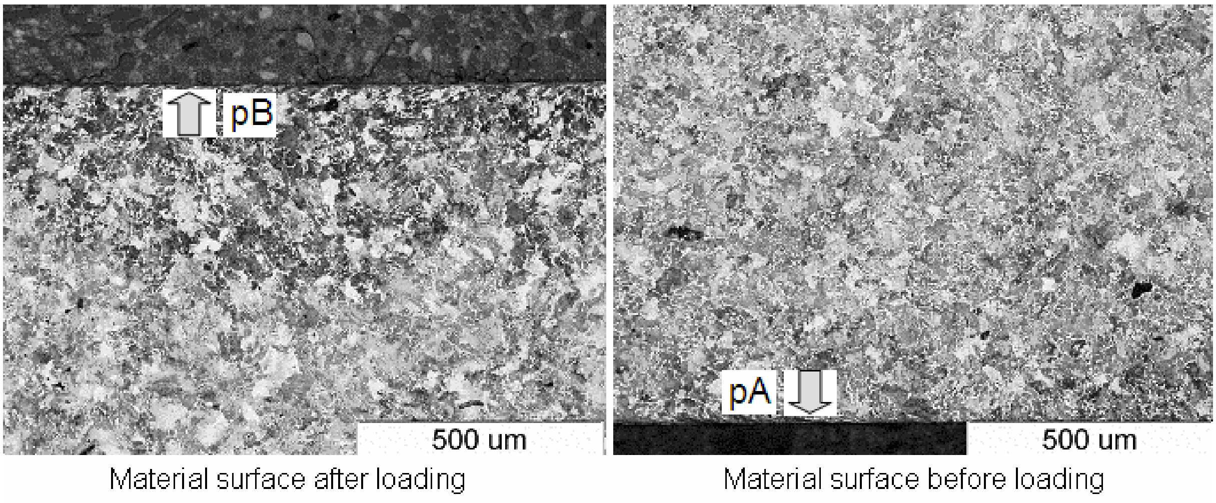

Fig. 1. Wheel tire material structure samples pA and pB
Rys. 1. Struktura próbki materiału obręczy: pA i pB

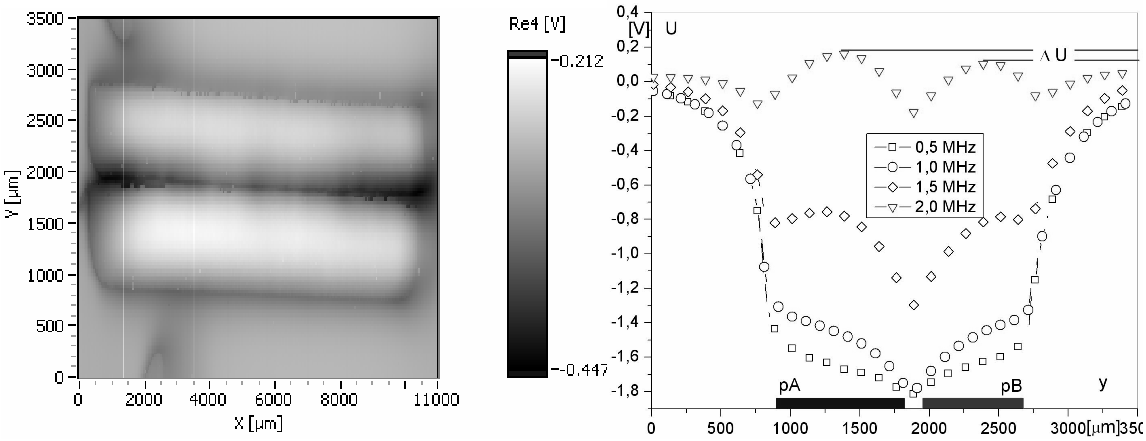

Fig. 2. BEMI eddy current image for samples pA and pBand amplitude-locus curves at different operating frequencies
Rys. 2. Obraz wiroprądowy mikroskopu BEMI dla próbek pA i pB i amplitudy sygnału w funkcji częstotliwości

5. MAGNETIC LEAKAGE FIELD USED AS A DIAGNOSTIC MEDIUM

The magnetic leakage field measured at the rolling surface varies in accordance with material's magnetic permeability, which in turn reflects the mechanical material's condition. This may be explained by example showing changes in initial magnetisation curves:

Material sample taken from a new wheel tire (before it has been assembled at the wheel) and material sample subjected to contact loads at AMSLER test rig (Fig.3a).

Hardened material sample taken from a wheel tire set on the wheel (Fig.3b).

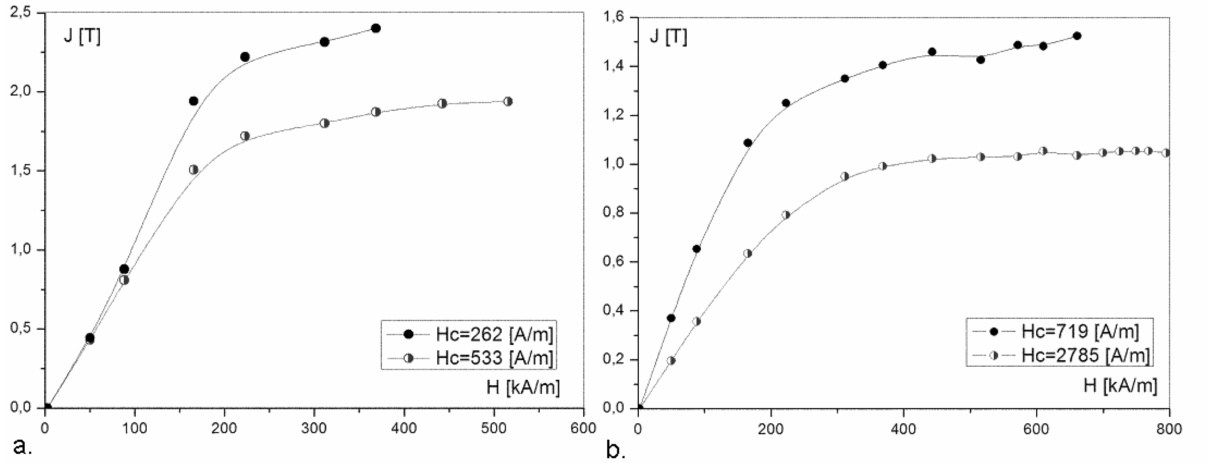

Fig. 3. Changes of magnetic parameters of the material subjected to deformation and hardening (a) fresh and degraded material (b)

Rys. 3. Zmiana parametrów magnetycznych materiału od odkształcenia plastycznego (a) i hartowania w stosunku do materiału nowego (b)

In both cases also a significant increase in the magnetic coercion Hc and a decrease in material's magnetic permeability are observed [5]. It is possible to detect changes in plastic strains along the rolling surface, impact of internal strains [5] as well as the phase changes of the material due to changes in material's magnetic parameters and magnetisation. In order to attain this result it is sufficient to measure magnetic field intensity (H_t) only along the wheel's rolling surface in the external magnetic field (e.g. Earth's magnetic field). However, a good measurement repeatability is only ensured by a local yoke magnetisation and with standard field probes (calibration), detecting magnetisation changes as shown in Fig.4**.**

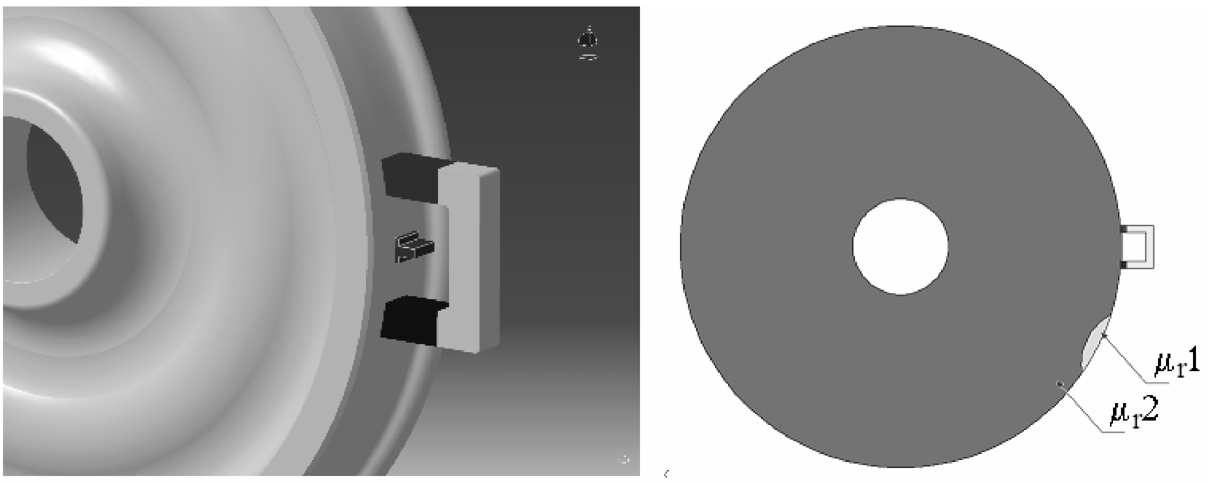

Fig. 4**.** Wheel set testing method

Rys. 4. Symulacyjne badanie zestawu kołowego

Detection of changes in material's magnetic parameters extends the range of known wheel set testing methods. Research is currently carried out in the Railway Engineering Department on a laboratory scale and in railway repair and maintenance works. Some investigation is performed also within a Ph.D. thesis.

Fig.5 shows: a) the numerical simulation of the test, b) the test rig, c) the results of the magnetic leakage field measurements for a new wheel, and d) the results of the magnetic leakage field measurements for a wheel with a damaged surface (change in material structure).

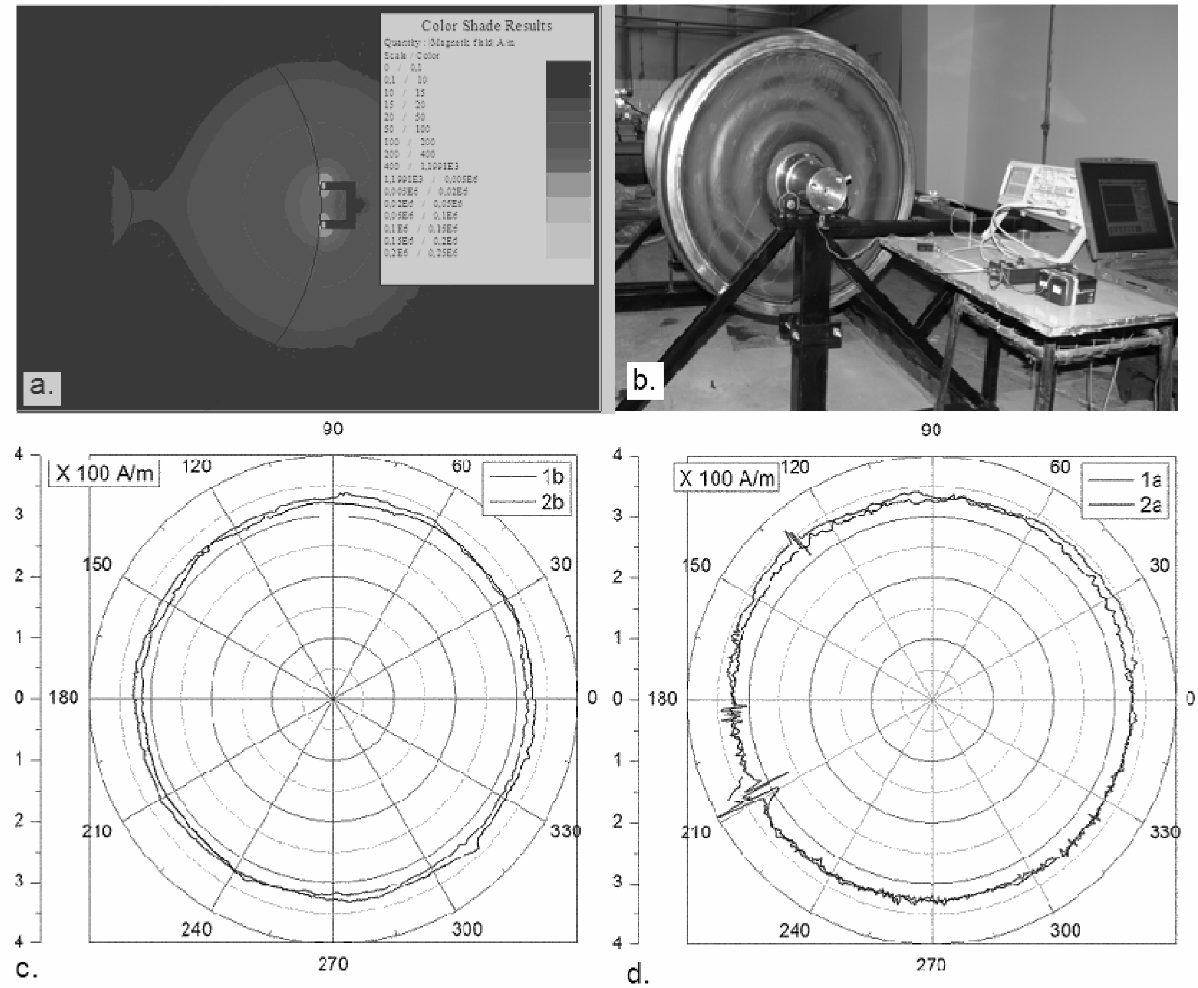

Fig. 5**.** Testing procedures and results for wheel sets
Rys. 5. Procedura badawcza zestawu kołowego

Additional information on the wheel set condition originating from magnetic measurements increases the diagnostic reliability, in particular during wheel set operation. This in turn increases rail transport safety.

6. CONCLUSIONS

Introducing additional magnetic tests to operational wheel set diagnostics provides additional information on material discontinuity as well as on structural changes (homogeneity). This is essential in order to ensure proper safety and operation of high speed trains. Table 3 sets out new testing methodology which will increase diagnostic reliability.

Tab. 3

Extended wheelset testing

Tested element	Testing method			
	geometry measurements	UT	magnetic leakage field tests by probes	ET
wheel	X	X	X	X
wheelset	X	X	X	X

The reliability of the proposed inspection should be validated by railway safety authorities. Expanding existing test rigs by adding some test probes does not significantly increase the quality costs.

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