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EVOLUTION OF DOMAIN STRUCTURE BEING THE DETERMINANT IN THE MECHANICAL FATIGUE PROCESS OF RAILWAY WHEELSET WHEEL MATERIAL

Summary. Investigation of fatigue processes on the basis of domain structure imaging makes possible identification of material zones and fatigue degree and will permit the introduction of changes in the wheel construction at the design stage. Investigation results of domain structure of wheelset's rolling surface subjected to contact loads and material samples subjected to cyclic loads have been presented in this paper.

ZMIANA STRUKTURY DOMENOWA MATERIAŁU OBRĘCZY ZESTAWU KOŁOWEGO OD OBCIĄŻEŃ ZMĘCZENIOWYCH

Streszczenie. Badanie procesów zmęczeniowych poprzez ocenę zmian struktury domenowej materiału jest metodą inwazyjną podobnie jak badanie krystalograficzne. Informacje uzyskane z badania domen magnetycznych umożliwiają prognozowanie stanu materiału, dlatego są badaniami diagnostycznymi wyprzedzającymi. Badania krystalograficzne ujawniają degradację struktury materiału dopiero w końcowej fazie „życia" materiału elementu. W artykule pokazano zmiany struktury domenowej materiału obręczy od obciążeń tocznych w odniesieniu stosunku do materiału wejściowego.

1. INTRODUCTION

During operation, the wheelset wheel is subjected to static and dynamic forces far exceeding allowable loads. The complexity of these loads is increased in case of driven wheels. Identification of material zones and fatigue degree makes possible introduction of changes in the wheel construction at the design stage. The paper presents investigation results for domain structure of wheel's rolling surface material. The surface was contact-loaded, while material samples were subjected to cyclic loads. Since material's magnetic parameters indicate the fatigue process development, the domain structure provides much diagnostic information on the material's condition. The domain structure tests are non-destructive tests and what's more, the information on material's degradation is obtained much sooner than in the case of metallographic tests.

2. DOMAIN STRUCTURE

Modern image analyzing techniques help to determine magnetic parameters of electrical steel very precisely. If magnetic material is not magnetically polarised and stress-free, then its domain structure is related to grain boundaries, as shown in Fig.1.

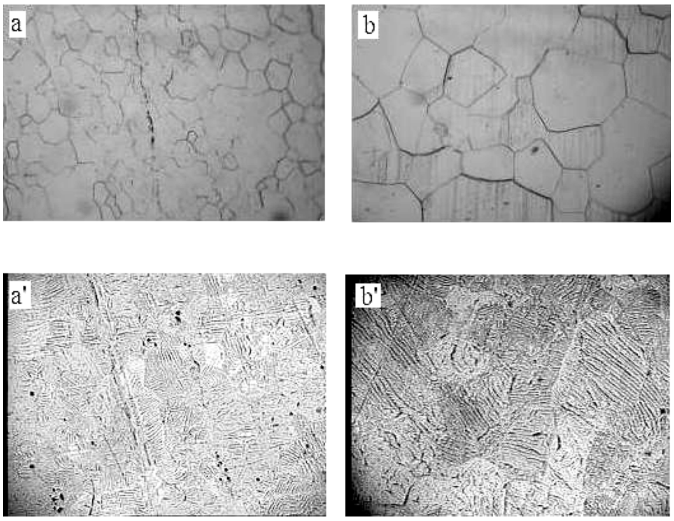

Fig. 1. Examples of crystal and domain structures
Rys. 1. Przykład struktury krystalicznej i domenowej

Domain structure of some materials, e.g. electrical steels used as transformer plates, is very distinct and easy to detect. When magnetisation is changed, domain images and domain arrangement change too.

3. MAGNETIC PARAMETERS vs. DOMAIN STRUCTURE

The magnetic parameters of iron alloys depend on their chemical composition [1], real structure, temperature and thermal processing. For instance, chemical composition of Fe-Cr-Ni alloys strongly influences their phase composition (Fig.2). The phase composition characterises magnetic parameters, and if it known then it is possible to qualify the material for magnetic testing.

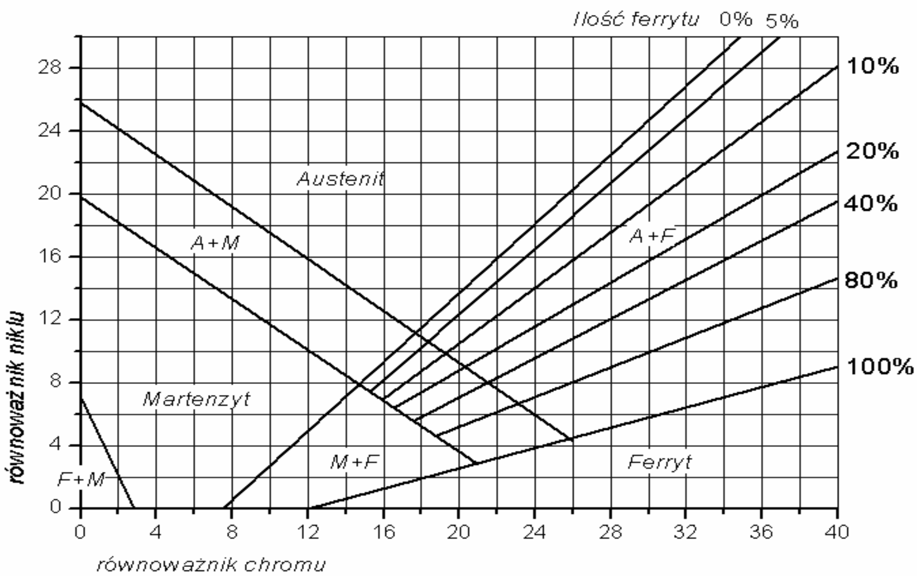

Fig. 2. Phase constitution of Fe-Cr-Ni alloys
Rys. 2. Wykres fazowy stopu Fe-Cr-Ni

Material's location in phase structure map is determined by following equivalents:
- chromium equivalent:

$$Cr_E = 1\times\%Cr + 1\times\%Mo + 1{,}5\times\%Si + 0{,}5\times\%Nb + ...(\%Ti, W, Ta, Al), \quad (1)$$

- nickel equivalent:

$$Ni_E = 1\times\%Ni + 30\times\%C + 1{,}5\times\%Si + 0{,}5\times\%Mn + ...(\%Co, N). \quad (2)$$

The ferrite percentage content k_f in austenitic alloys may be determined from expression:

$$k_f = \left(\frac{j_w}{V_p} - J_a\right) / \left(J_{sf} - J_a\right) \quad (3)$$

where: J_a - magnetisation (austenite) ($2{,}31\cdot10^{-4}$ T), V_p - material's volume, J_s - ferrite magnetisation, j_w – magnetic dipole moment.

Pure austenite is a very poor magnetic material. Materials outside austenite range may be magnetically tested. Austenitic-martensitic steels are used in wheelset construction.

Magnetic susceptibility ($\chi_w = \mu_w - 1$) in magnetic materials as well as in constructional steels is related to coercion intensity. This relationship is constant for a given material in accordance with expression:

$$\chi \cdot H_C = \text{const.} \quad (4)$$

If the significant impact of domain structure is considered and taken into account on the basis of the effective thickness of domain walls δ and average domain width L, then the above expression may be re-written as:

$$\chi \cdot H_C \le J_s \cdot \frac{\delta}{L}, \quad (5)$$

where Js –saturation magnetisation.

In low-carbon and low-alloyed steels the above effects always develop in the same way. The correction intensity increases, while magnetic permeability decreases In case of P54T steel used for wheelset tyres this process is observed during plastic straining (Fig.3a). Similar changes in magnetic parameters take place during hardening (Fig.3b).

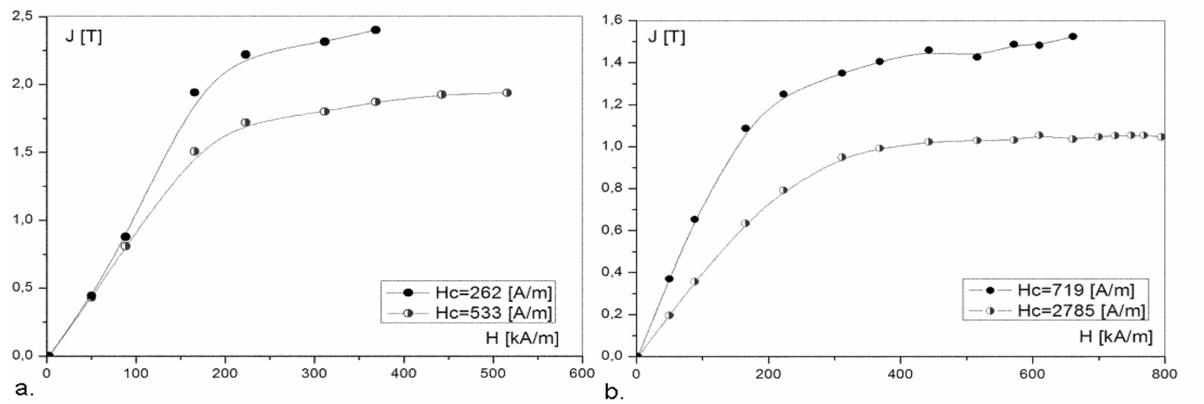

Fig. 3. Changes of initial magnetisation curve due to a) plastic straining, b) hardening
Rys. 3. Zmiana krzywej pierwotnego magnesowania od odkształceń plastycznych –a, i hartowania - b

Degradation of material structure caused by mechanical fatigue cyclic or contact loads is related to significant decrease in magnetic permeability and increased coercion.

4. DOMAIN STRUCTURE OF CONSTRUCTIONAL STEELS

Domain structure of weak magnetic materials such as austenitic-martensitic steels is poor and its photography is difficult.

Figure 4 shows images of material structure of two wheel tyres (one new and one used) upper layers, as well as corresponding photos of domain structures. When material is subjected to plastic strain, then it loses its original domain structure. The influence of stress in the strained layer on the domain system must also be considered.

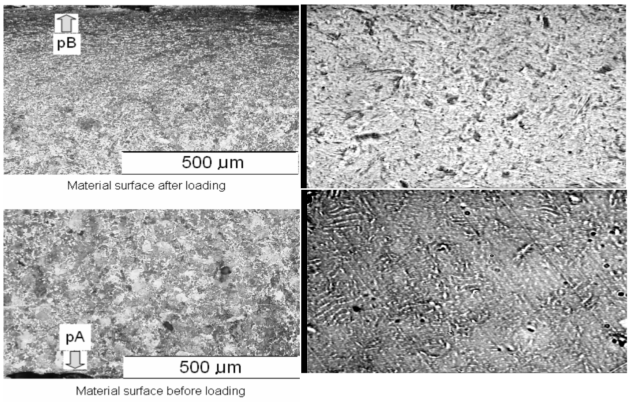

Fig. 4 Material structure with corresponding domain structure
Rys. 4. Struktura krystaliczna materiału i przynależna struktura domenowa

5. CONCLUSION

Introducing additional tests of real fatigue loads and their localisation into the process of wheelset design will result in using dynamic coefficients more actual than those obtained by vehicle vibration tests. Investigation of domain structures widens the range of information obtained from crystallographic tests.

Literature

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