Abstract

Reliability of operation of various objects of everyday life (cars, airplanes, various types of building structures, components of advanced machinery) is crucial to ensure the safety of their direct users and other people. Therefore, it is necessary to conduct constant monitoring of the technical condition of these objects. The diagnostic methods that allow, in a non-interfering way in the material structure, to investigate the condition and to assess e.g., the usage of a given object are the scope of non-destructive testing. There are many methods of non-destructive testing of materials. One of the methods that has been intensively developed recently is the Magnetic Barkhausen Noise (MBN) method.

In this dissertation, several studies have been carried out on the use of time-frequency (*TF*) transformations for the analysis of MBN signals. The nature and dynamics of the Barkhausen phenomenon depend on the type of material and on the homogeneity of its structure. In the literature one can find various types of MBN signal characteristics. The development of areas in the material having different microstructural properties (during production or usage) influences the behaviour of the magnetization process, resulting in distinguishable phases of intensification of the domain structure reorganization process. Consequently, this is reflected in the course of the Barkhausen phenomenon. Therefore, standard methods of signal analysis may not be sufficient. In the literature, one has mainly encountered the analysis of the MBN signal in the time or frequency domain. Only a few works have used the time-frequency representation, but these analyses have only been performed in a qualitative approach. Therefore, the object of the present work was to develop procedures and algorithms to observe changes in the dynamics of the phenomenon using *TF* transformations.

The thesis of the dissertation is: multi-variable analysis of the time-frequency representation of the Barkhausen noise phenomenon, makes it possible to obtain new or complementary information on the quality of steel materials treated. To test this thesis, several objectives were realized. One of them was to build a measurement system, including: dedicated analogue signal processing system, magnetizing field generation system, positioning system and measuring transducer. To integrate all these elements a dedicated software was created, which enabled the automation of the measurement.

The developed system was used to carry out several measurement experiments which allowed the acquisition of numerous data. Then, these data became the basis for developing analyses of the MBN phenomenon dynamics using the *TF* transformation. Two types of *TF* distributions of MBN signals were analysed: focused and multi-phase. *TF* representations allowed to develop new methods of MBN signal analysis. An important achievement was the development of procedures for feature extraction from *TF* distributions, including a method enabling characterization of areas of highest MBN activity. As a result, the obtained characteristics of *TF* features allowed to obtain even twice higher distinguishability between the states of materials in selected ranges of measurements, which ultimately supplemented the primary information. In the context of multi-phase distributions, the developed feature extraction procedures were supplemented with a method for extracting sub-periods of activity. New information about the constituent factors affecting the directional properties of materials was obtained, as well as more stable angular characteristics of the features reflecting the resultant properties.

An important area of work was the analysis of the influence of measurement and computational parameters on the character and quality of information encoded in the *TF* feature vector. It allowed to create a systematic approach to the selection of conditions for measurements and analyses depending on the type of tested material and expected characteristics of the MBN signal. A study of the possibility of using different *TF* representations was also carried out, showing the higher efficiency of the STFT transform compared to others. The repeatability and degree of order of the extracted *TF* feature characteristics, as well as the computational complexity were considered.

An important part of the dissertation was the work on analysing information from multiple features obtained to build a more comprehensive knowledge on the condition of the material under

study. In this aspect, a new way of integrating data extracted from MBN signals for material property evaluation was proposed. For this purpose, a deep neural network model has been used to perform multi-variable analysis and data integration. The used solution allows to realize the process of quantification of information (definition and selection of features) contained in the *TF* distributions without the intervention of an expert/operator. The developed model was then supplemented with an update algorithm. It has shown great accuracy in distinguishing materials subjected to surface engineering methods.

It should also be emphasized that the completed work has interdisciplinary character, not only related to the field of electrical engineering, electronics and automation, but also computer and materials engineering. Within the scope of this work, a measurement system was built, new algorithms for MBN data processing were developed and implemented, an extensive analysis of measurement and computational conditions was performed, and a solution for the integration of information obtained from MBN signals using deep neural networks was proposed. The research results presented in this dissertation confirm the correctness of the assumed thesis.