Microstructure Evaluation of Ductile Cast Iron and Numerical Modal Analysis

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This work is closely connected with the evaluation of the microstructure of the cast iron with the spherical shape of graphite. The given work is mainly focused on mechanical properties, chemical composition and microstructure, which are important to be known as an input parameters for computational modelling and numerical analysis. The external factors, influencing the measure of the mechanical damping, include the measure of the mechanical loading, loading frequency and temperature. These factors have the influence on the process of the mechanical energy distribution in materials. Eigenshapes as well as eifenfreguencies were investigated by modal analysis using finite element method (FEM).

Keywords: cast iron, microstructure, mechanical properties, modal analysis

1 Introduction

Experimental modal analysis is closely connected with the process of the experimental modal parameters determination (eigenfrequencies, eigenshapes and damping) of linear invariant systems in time. In present, the experimental modal analysis represents interdisciplinary area, which stands for mutual connection of signals as well as interaction of information technology electrotechnics, mechanics theory, dumping (vibrations), acoustics and control of various devices in mechanical industry. In addition, this analysis stands also for specification of steps for estimation of parameters from the applied mathematics [2]. There is the increase of the performance and speed of operating construction and parts during operation, the result of which is formation of undesirable vibrations [3]. This undesirable features and critical machine vibration violation negatively impacts on their life time, reliability, and they may cause a machine damage and accident. Absorption of material vibration can be considered as its diminishing ability. Factors that affect the material damping include viscoelasticity, thermoelasticity, acoustic effects, or magnetism. Other factors include the amount of mechanical stress, load frequency, or temperature [6]. Eigenshapes and eigenfrequencies are closely related to the internal damping of the material and therefore the numerical part is focused on the finite element modal analysis in the ADINA software [10].

2 Material characteristic

The experimental material was a cast iron with regular grained graphite the graphite particle [4] size was from 15 to 30 μm (Figure 1). From a microstructural point of view, the matrix consists of ferrite and lamellar perlite containing more than 2%. The dispersion of the perlite was from 0.3 to 0.8 μm (Figure 2) [8].

From a microstructural point of view, the matrix consists of ferrite and lamellar perlite containing more than 2%. The dispersion of the perlite was from 0.3 to 0.8 μm (Figure 2). The microstructure was evaluated according to STN (Slovak Technical Standards) 42 0461 using the Vega 3 Tescan thermoemission electron microscope. The bulb shape of the graphite does not cause a stress concentration in comparison with lamellar type of graphite (Figure 3 – 4). It is particularly suitable for machine bases, engine cylinders and castings of high stressed parts (Table 1). The content of alloying elements of the ductile cast iron was measured from the whole volume of the sample by the EDX-7000 detector (Table 2) [5, 9].

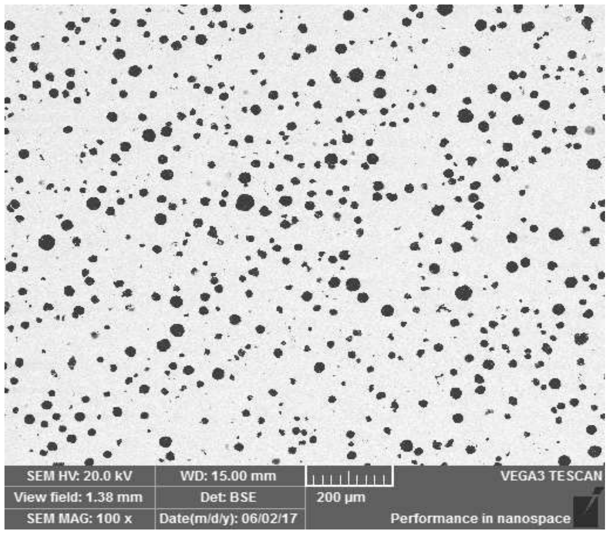

Fig. 1 *Regular grained shape of ductile iron graphite.*

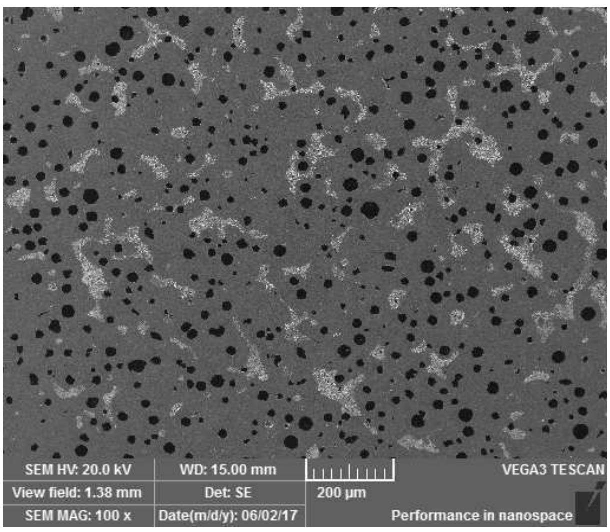

Fig. 2 *Feritic-pearlitic matrix of ductile cast iron.*

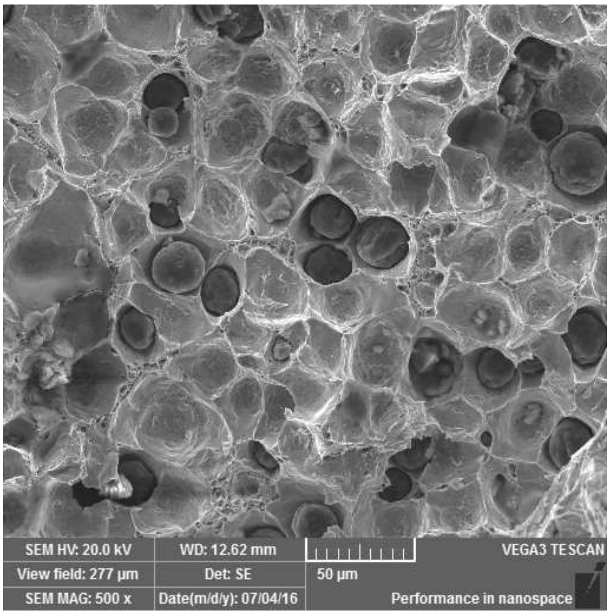

Fig. 3 *Cavity micromorphology of the casting surface of ductile cast iron.*

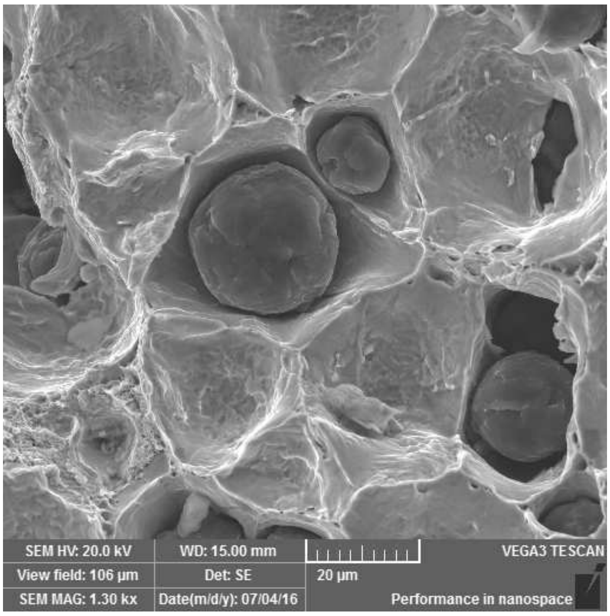

Fig. 4 *Detail of spherical graphite in the fracture area.*

Tab. 1 *Mechanical properties*

R_m (MPa)	$R_{p0,2}$ (MPa)	A (%)	HB	E (GPa)
380 - 900	250 - 600	2-25	120 - 350	140 - 185

Tab. 2 *Content of alloying elements in wt. %*

Si	Cu	P	Mn	Ca
2.758	0.504	0.379	0.373	0.122

3 Experimental modal analysis

Experimental modal analysis stands for the process of experimental determination of modal parameters (eigenshapes, eigenfrequencies) of linear systems. The damping properties of the material can be used with mathematical models to design damping systems and they can be also applied for prediction of their performance. The dumping structure based on homogeneous layer representing the tested beam sample has good results, but in some applications the damping structure may consist of two or more layers with significantly different properties [6]. The schematic image of the device for measuring of the damping properties is shown in Figure 5 [1]. As a part of the measuring device, the multi-analyzer PULSE 12 software system for vibro-acoustic measurements is used for evaluation of measurement results. When examining the dynamic effects of an excitation system, it is necessary to take into account the linearity of the system and this fact means that the response of the system is directly proportional to the corresponding excitement [2].

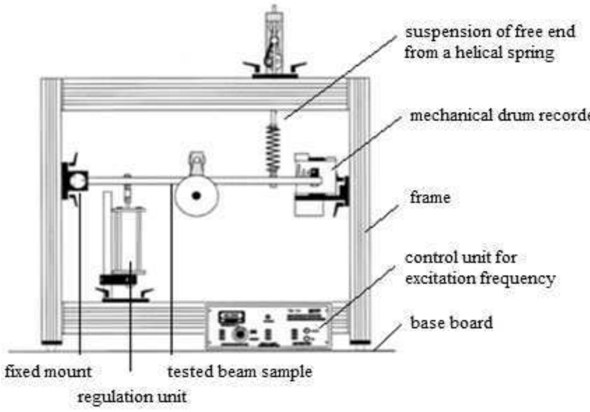

Fig. 5 *Detailed description of the measuring device [1]*

Basic conception proposal of the device for measurement of strength and damping properties relating to construction (structural) materials is based on requirements for the given device from the aspect of the determination of measurement methods for the mentioned properties. The methods and individual steps of measurement in relation to damping properties for construction (structural) materials are based on the valid standards. The model of sample (Figure 6) had precisely defined dimensions and it was according to ASTM E756 (Standart test method for measuring vibration-damping properties of materials) [1].

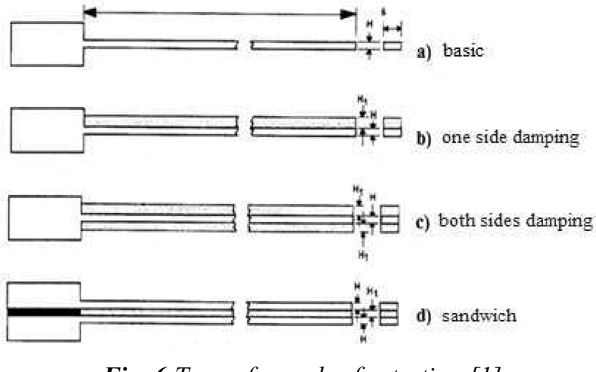

Fig. 6 *Type of samples for testing [1]*

4 Numerical analysis

The eigenshapes and eigenfrequencies (Tab. 3) represent an important factor in oscillation of structural materials [9]. The model of sample had precisely defined dimensions and it was according to ASTM E756. Measurement of the homogeneous beam sample (Figure 7) was performed from the aspect of the strength and damping properties of the materials, while the input parameters of the investigated ductile cast iron were predefined and modal analysis was performed using the finite element method in the ADINA software environment [7,10].

Tab. 3 *Eigenshapes and eigenfrequencies*

Eigenshapes	Frequency (Hz)
1	7.76591E+01
2	4.86928E+02
3	5.11581E+02
4	1.30376E+03
5	1.36697E+03
6	2.69083E+03
7	3.04368E+03

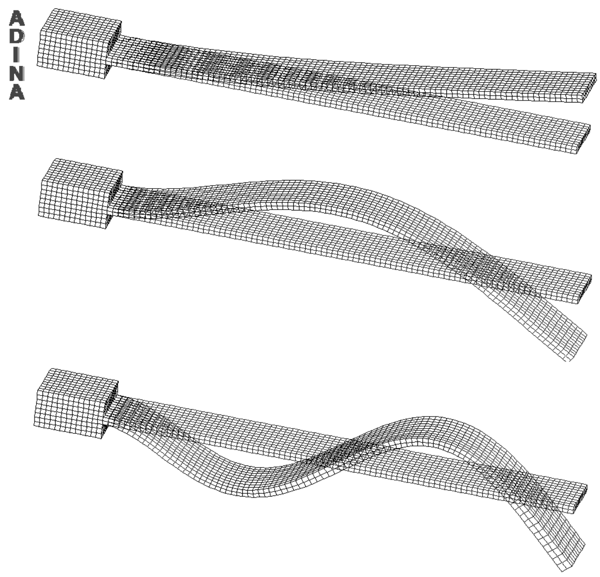

Fig. *7 Selected first eigenshapes of the homogeneous beam*

5 Conclusions

In production of heavy duty machines and devices, which have to operate under the continuous cyclic loading, the dumping properties have to be taken into account, because the increased vibrations have a negative effect on functionality of operating machines, which can be totally damaged or they can even cause any accident. The mentioned facts make us look for ways to improve of limiting technical parameters and operating efficiency by selection of the right material. Modal analysis is a field of study that combines signal processing and computational interaction, mechanics theory, oscillation, acoustics, applied mathematics, and engineering prediction. Internal damping occurs in the structure of the material and can be caused by imperfection of this material. It is therefore necessary to have all important knowledge about the specific material before its usage in the operation.

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