Measuring of Vibration-Damping Properties of Cast Iron

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Nowadays, ever increasing demands are being made on equipment and machine structures. This fact negatively affects their lifespan, reliability and security. Internal damping is caused by material malfunctions in the microstructure, thermoelastic effects, movement of dislocations or the effects of swirling currents. This paper deals with microstructure, chemical composition and mechanical properties of ductile iron. These data are required as input parameters for computational modeling and numerical analysis. The numerical part is focused on the modal analysis of the homogeneous beam sample by finite element method in the ADINA software environment.

Keywords: cast iron, finite element methods, microstructure, mechanical properties

1 Introduction

Nowadays, increasing demands are being made on machine constructions or parts and equipment in operation. 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 [1]. 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. 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. [1,2].

2 Material characteristics

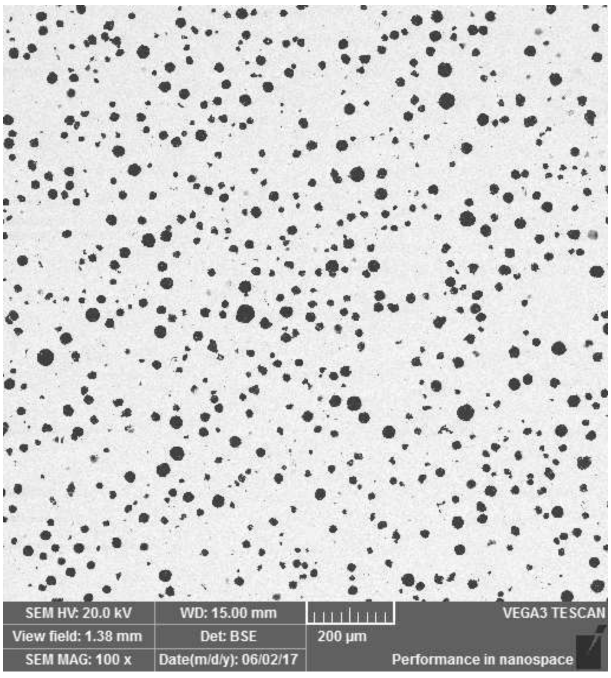

Fig. 1 *Regular grained shape of ductile iron graphite.*

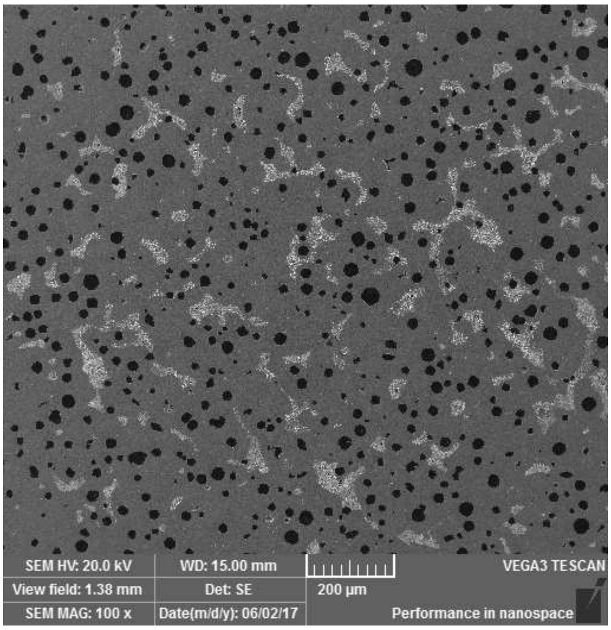

Fig. 2 *Ferritic-pearlitic matrix of ductile cast iron.*

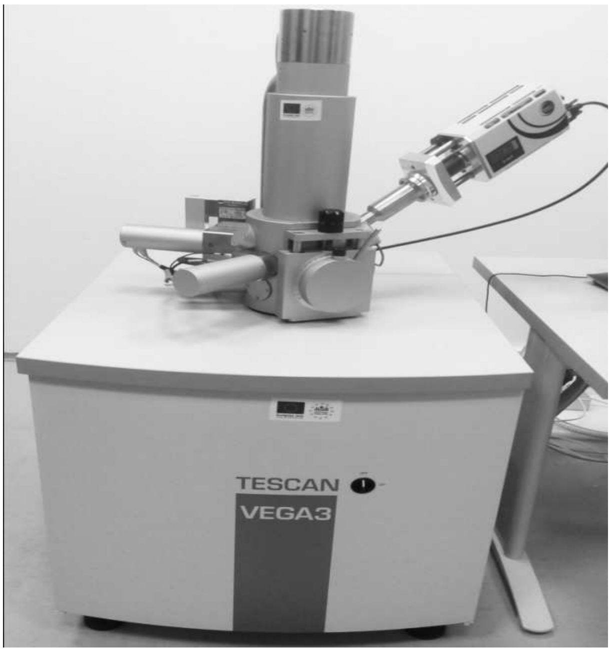

Fig. 3*Vega 3 Tescan thermoemission electron microscope*

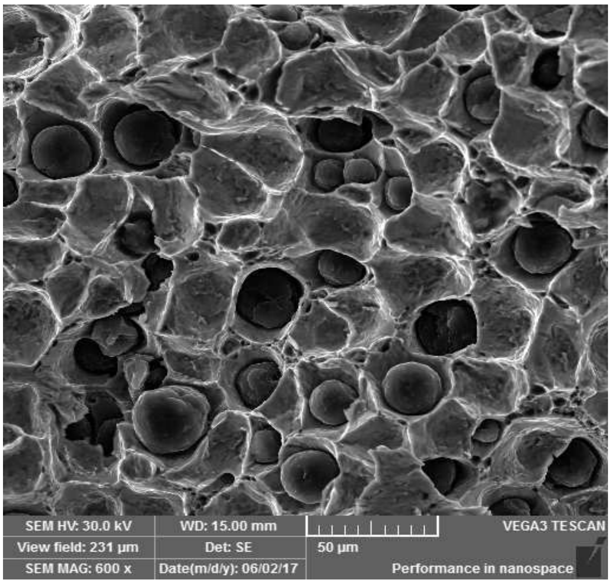

Fig. 4 *Cavity micromorphology of the casting surface of ductile cast iron.*

The experimental material was a cast iron with regular grained graphite the graphite particle 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). The microstructure was evaluated according to STN (Slovak Technical Standards) 42 0461 using the Vega 3 Tescan thermoemission electron microscope (Figure 3).

The bulb shape of the graphite does not cause a stress concentration in comparison with lamellar type of graphite (Figure 4 – 5) [3, 4, 5, 6].

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) [3, 4, 5, 6].

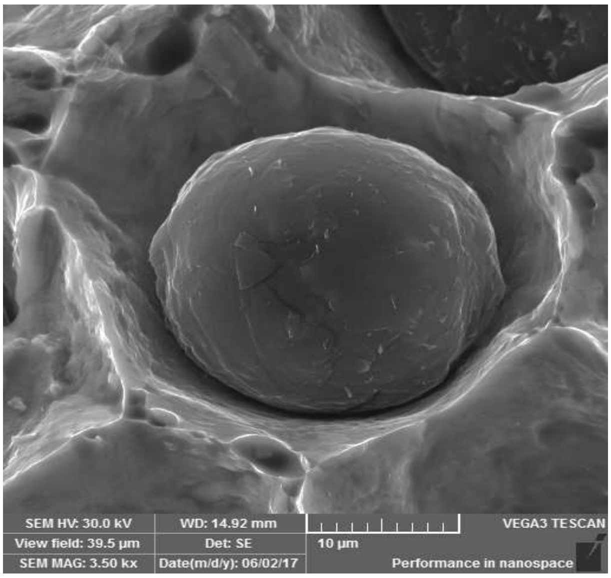

Fig. 5 *Detail of globular graphite in the fracture area.*

Tab. 1 *Mechanical properties*

R_m (MPa)	$R_{p0,2}$ (MPa)	R_{mt} (MPa)	A (%)	HB	E (GPa)
380 - 900	250 - 600	600 - 1200	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 way and the method of experimental measurement are standardised. 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. According to the frequency criterion, experimental measurements of the internal damping and modulus of elasticity are divided into infrasonic (10-4 to 102 Hz), sound (102 to 104 Hz), ultrasonic (104 to 108 Hz) and hypersonic (109 to 1011 Hz) types of measuremet. The schematic image of the device for measuring of the damping properties is shown in Figure 6. 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 accout the linearity of the system and this fact means that the response of the system is directly proportional to the corresponding excitement [1, 2, 6, 7].

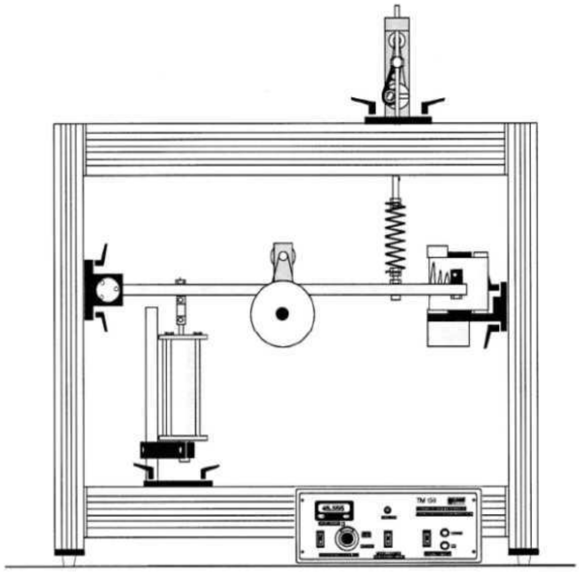

Fig. 6 *Scheme of the measuring device*

4 Finite element modal analysis

The own shapes (eigenshapes) and own frequencies (eigenfrequencies) represent an important factor in oscillation of structural materials (Table 3). 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 (Figure 8) was performed using the finite element method in the ADINA software environment [1, 9, 10].

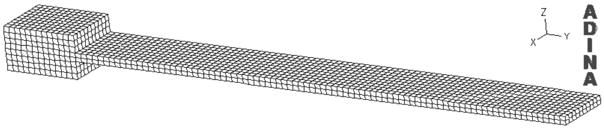

Fig. 7 *Sample Model based on Finite Element Method*

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

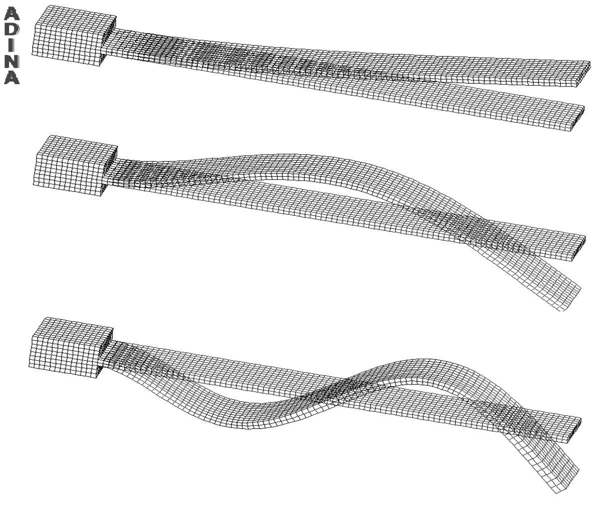

Fig. 8 *Selected first eigenshapes of the homogeneous beam*

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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