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ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (2299-2944)
Volume 2020
Issue 1/2020

23 – 26

10.24425/afe.2020.131277

4/1

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

Influence of Cast Iron Modification on Free Vibration Frequency of Casting

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Received 19.06.2019; accepted in revised form 11.10.2019

Abstract

The paper presents the results of investigations concerning the influence of gray cast iron modification on free vibration frequency of the disc casting. Three different chemical composition melts of gray cast iron were prepared in induction furnace. During gravity casting 0.05% and 0.3% mass of the Inolate modifier was added on stream of metal for changing graphite flakes in castings. Sound signal vibration of cast iron sample was registered by means on microphone for free vibration frequency measurements. Decreasing of free vibration frequency of modified cast iron in comparison with non modified castings was observed. Higher contents of modifier causes more decreasing of free vibration frequency. Cast iron with smaller contents of carbon and silicon have higher free vibration frequency in comparison with eutectic composition cast iron. Hardness of examined cast iron is lower when the more modifier is added during modification process. Free frequency is smaller with smaller Brinell hardness of disc casting. It was concluded that control of free vibration frequency of disc castings by means of chemical composition and modification process can improved comfort and safety of working parts.

Keywords: Gray cast iron, Modification process, Free vibration frequency of casting

1. Introduction

The free vibrations of castings are caused by deflection from position of secular equilibrium and are not dampened by no operating forces on. Frequency of non-dampened vibrations is called the free (own) frequency of vibrations of the body and it is his characteristic feature. Free vibrations execute elastic bodies, if amplitude of vibrations is not large and a Hooke's law is carried out. Frequency of free vibrations depends only on physical properties of material and shape of body. Casting executes free vibrations with certain frequency regardless of method and force of excitation. Bodies can have much frequencies of free vibrations. If frequency of vibrations does not depend on amplitude the oscilating system is linear in this case. Amplitude of vibrations depends on initial deflection (potential energy) or from the initial (kinetic energy) velocity given to the body. Normal (own) oscillation is a standing wave in the body.

Undesirable and such, that conduces to more rapid wearing out of the system the phenomenon of resonance comes forward then, when frequency of exciting force is covered with frequency of free vibrations of the body. The phenomenon of resonance can be limited through the change of such parameters: mass of the mode, place of fixing of elements or dampening in the body. In case of, when frequency of exciting is near to frequency of free vibrations of the body, there is the beat phenomenon [1-3].

In the real materials dampaning of vibrations comes forward as a result of their dissipation and absorption of energy. Dissipation consists in the reflection of oscillation in many directions on the elements of underlying structure of material, absorption of wave but consists in her substituting of energy by other the figure, usually there is then thermal energy [4,5].

Size of grain of metal matrix and precipitates in a structure, elastic properties of interphase surface also quality of connection of matrix-precipitates influence on propagation of vibrations. Absorption of energy is caused by the mechanism of internal friction the generation of dislocations compensative tensions in interface of matrix and precipitates. Dislocations form as a result of differences in thermal expansion of matrix and precipitates also sliding along the borders of grains and to the mutual movement of interphase surfaces matrix-graphite [6-8].

In the case of smaller size grains, their surface is larger, which contribute to dispersion of vibration energy and improves dampening properties of material. [9]. With the increase of amount and size of graphite flakes the dampening of vibrations grows. Increasing of interphase surface of graphite-matrix increases a number and dislocation density, what interprets the best capacity for dampening of vibrations of cast-iron with the graphite flake comparatively with cast iron with a spheroidal graphite. Surface interphase of graphite-matrix in cast-iron with the graphite flake is larger from such surface in cast-iron with a spheroidal graphite.

Than a difference between of Young modulus of cast iron matrix and graphite precipitates, capacity for the dampening of vibrations will be better [9]. For example weak, as well as very good connection between matrix and reinforcing phase in composite materials can potentially remedy the capacity for the dampening of vibrations.

Weak connection on interphase matrix-reinforcement will promote to the increase of ability of composite to the dampening of vibrations as a result of presence of mechanism of sliding friction, but strong connection can conduce to the increase of dislocation density near-by a interphase matrix-reinforcement [10-13]. Better capacity for the dampening of vibrations shows up reduction of free frequency, and fatique consumption is lower in this case. There is lower probability of resonanse vibration and safety increases.

2. Material and researches methodology

Research of own frequency of vibrations of castings was executed by a method that consists in excitation to casting vibration placed on the special support for help electromagnetic hammer. Microphone placed close of casting registers complete description of oscillation. The hammer used in research was following features: range of frequency to 10 kHz, mass 0.1 kg, diameter of head a 1.5 cm. A microphone had next characteristics: range of frequency: 100 Hz - 12 kHz, dynamic range: 40 dB-140 dB. A ten measurements was executed for every casting.

Measurements of hardness was executed on 10 random selected castings from every melt by the Brinell method according to the norm of PN-EN ISO 6506-1 [14]. The spherical penetrator made from carbides, diameter of 5 mm and at load of 7 kN, was applied. Time of load action was 10 s. Hardness was measured on 4 places on the casting surface. The automatic measurements were executed, enumerating a result from the diameter of intendation according to a norm.

Three melts of grey cast-iron was made in the induction furnace of middle frequency about the capacity of 50 kg modify that addition of 0.05% and 0.3% of modifier of Inolate 30 about composition: 75% Si, 1.1% Sr, 0.01% Ca, 0.05% Al. Disc castings 300 mm in diameter and the thickness of a 15 mm were cast to the mould executed from moulding sand consists of quartz sand and bentonite. During gravity pouring, the modifier, about 0.2-0.7 mm in size was added on the stream of liquid metal about the temperature of 1430°C. Chemical composition of cast iron melts with different factor of eutectic saturation is presented in a Table 1.

Table 1.
Chemical composition of cast iron

Melt no.	Content of element, % mass						
	C	Si	Mn	Cr	Cu	S	P
1	3.75	1.65	0.66	0.22	0.43	0.06	0.02
2	3.66	1.52	0.63	0.27	0.32	0.08	0.03
3	3.55	1.40	0.62	0.22	0.22	0.06	0.03

Graphite in castings was investigated by the quantitative metallography method where the amount and length of graphite precipitates on 100 measuring areas by an area 1 mm^2 each were measured. All measurements were made on non-etched microsection at 100 times magnification.

3. Results of researches

Change of length of graphite and increasing the number of flakes of greater in the investigated cast irons was the aim of modification procedure investigated cast irons and the same the management by free frequency vibrations of disc castings, but not classic effect of inoculation modification. It follows from a Table 1, that all investigated cast-irons have near eutectic chemical composition and have large ability to grafitize without modification. Applied additions of modifier, less substantially from the modifications recommended in classic procedure had for an object determination of range and changes of influence of amount of modifier in relay graphite precipitates.

In Table 2, the results of measuring of length of graphite precipitates are presented in cast-iron executed according to a norm PN ISO 945-1 2008. The placed values are arithmetic mean.

Table 2.
Distribution of average length of graphite flakes

Melt no.	Percentage fraction of graphite length for each class								
	without modification			modification 0.05%			modification 0.3%		
	3	4	5	3	4	5	3	4	5
1	1.9	22.1	76.0	6.9	26.3	66.8	20.8	35.8	43.4
2	0.0	25.7	74.3	8.0	22.0	70.0	13.0	31.2	55.8
3	4.1	41.8	54.1	12.9	28.3	58.8	19.2	42.2	38.6

Examples of graphite precipitates in non-modified and modified examined cast iron were presented in Fig.1-3.

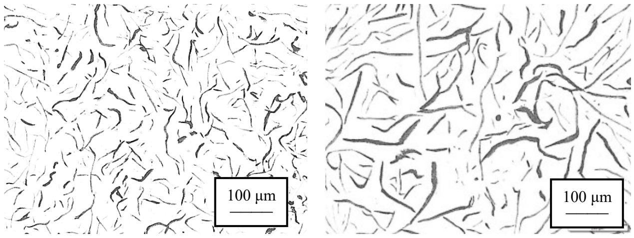

Fig. 1. Graphite flakes in non-modified (left) and modified 0.3% modifier (right) cast iron, melt 1

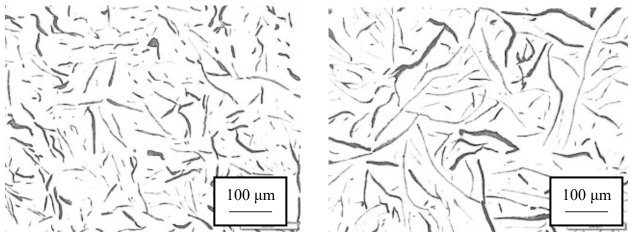

Fig. 2. Graphite flakes in non-modified (left) and modified 0.3% modifier (right) cast iron, melt 2

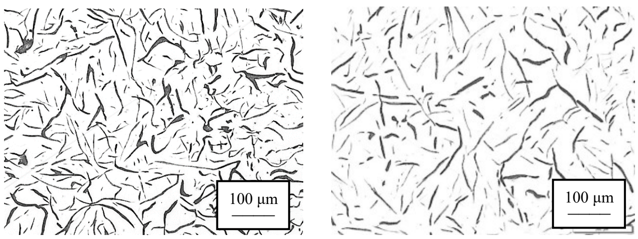

Fig. 3. Graphite flakes in non-modified (left) and modified 0.3% modifier (right) cast iron, melt 3.

The results of researches of graphite length in the investigated cast irons specify simply on the increasing of graphite precipitates length as a results of modification, that stronger, than eutectic saturation ratio of cast iron is anymore. Addition of 0.3% modifier stronger increases of length of precipitates graphite. Modification causes the increase of size heterogeneity of graphite, what is very substantial influence on the estimation of quality of castings and their firmness. In non-modified cast iron average graphite length was only in class 4 and 5, in modified cast iron average graphite length was in class 3,4 and 5 (Table 2). The average values of free frequency of vibrations of casting for the investigated melts are presented in Table 3.

Table 3.
Average free frequency of vibration of cast iron

Melt no.	Free frequency of vibration of cast iron, Hz		
	without modification	modification 0.05%	modification 0.3%
1	1029	1006	988
2	1080	1055	1033
3	1139	1085	1063

The average values of Brinell hardness of examined castings were presented in Table 4.

Table 4.
Average values of Brinell hardness of castings

Melt no.	Average values of Brinell hardness, MPa		
	without modification	modification 0.05%	modification 0.3%
1	205	191	183
2	220	213	206
3	232	212	200

Estimating the results of research of hardness of cast iron noticing follows, that procedure of modification causes reduction of hardness in each of the investigated melts. The increasing of amount of modifier from content of 0.05% to 0.3% (6 times) increases the effect of reduction of hardness. Hardness of non-modified and modified cast iron depends on chemical composition of the cast iron expounded by the value of factor of eutectic saturation. Cast iron with the greater factor of eutectic saturation has less hardness. Probably, crystallization of a small amount of austenite dendrites (primary phase) before crystallization of eutectic phase causes the increasing of hardness and some strengthening of the alloy. Graphite flakes in all cast irons are very alike in relation to a kind, placing and sizes. Procedure of modification decreasing the differences of hardness of all investigated cast-irons. The functional dependence of own frequency with hardness of cast-iron is presented on a Fig. 4 (Tab.3 and 4) and with modifier content in Fig.5.

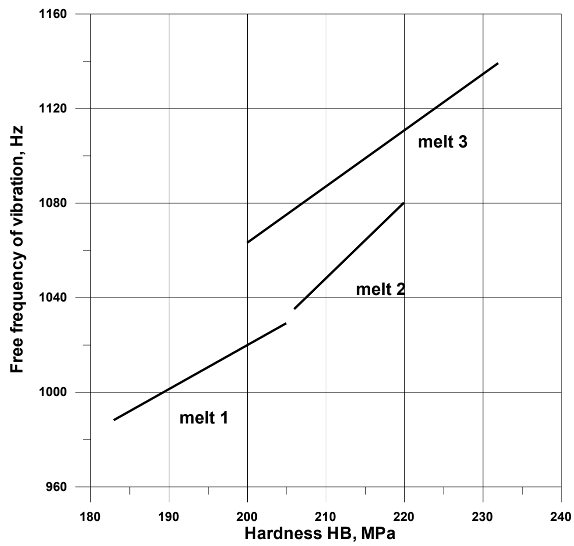

Fig. 4. Change of average free frequency with hardness of cast iron

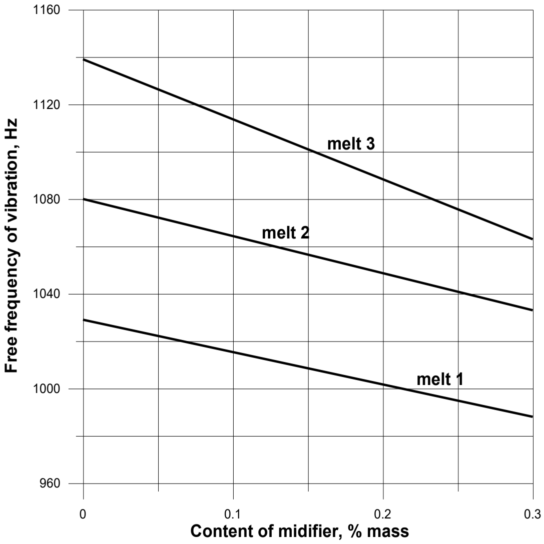

Fig. 5. Change of average free frequency with modifier content in cast iron

4. Conclusions

On the basis of presented higher results of researches and also leaning on literary materials it is possible to present the following suggestions:

1. Chemical composition of castings executed from grey cast-iron has an influence in relay own frequency of casting from cast-iron with the graphite flake,
2. With the increasing of carbon content in cast-iron own frequency of vibrations decreasing,
3. The decline of carbon content in grey cast-iron causes the increase of homogeneity of own frequency of vibration of castings and high content of C and Si in cast-iron causes the increasing of heterogencity of free frequency of casting.
4. The increase of participation of modifier in modification procedure increases the effect of modification,
5. The increase of addition of modifier on a metal stream during the pouring of moulds in modification procedure causes reduction of value of own frequency of vibration.

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