J. KASIŃSKA, D. MYSZKA

ISSN 0543-5846
METABK 59(4) 459-462 (2020)
UDC – UDK 669.85/86:669.1:539.26:620.18:620.178.1 = 111

INFLUENCE OF RARE EARTHS METALS (REM) ON THE STRUCTURE AND SELECTED PROPERTIES OF GREY CAST IRON

Received – Primljeno: 2020-02-20
Accepted – Prihvaćeno: 2020-06-10
Original Scientific Paper – Izvorni znanstveni rad

The paper presents the results of tests carried out on grey cast iron obtained in laboratory conditions. Cast iron EN-GJL-200 was enriched with REM at 0,3 % wt. in relation to the weight of the charge metal. The presence of REM was found only in some elements of the structure, i.e. in ferrite and in precipitations. An 18 % decrease in the coefficient of friction was observed for REM-modified cast iron as compared to the base cast iron.

Keywords: rare earth metals, grey iron, X-ray analysis, microstructure, wear resistance

INTRODUCTION

Rare earth metals (REM) are widely used in the metallurgical industry, primarily as alloying elements, reducing agents, deoxidizers and desulfurizers. They are typically used in cast steel to improve its mechanical properties [1 – 2], but a higher proportion of REM is utilized in the production of cast iron. Iron castings manufactured with REM addition include cast iron shafts and ingot moulds, RE - Mg treated ductile iron pipes, car parts, locomotive engine parts, cast iron radiators and abrasion resistant alloys with a moderate Mn content. Although most characteristics of REM-containing materials have already been studied and described, new areas appear where the effect of REM is not fully understood. One of such areas is the influence of REM on the cast iron structure during modern heat treatment processes [3]. Gou Erjun et al. [4] used rare earths to modify high-chromium cast iron containing 2,5 – 2,7 % carbon, 15 – 18 % chromium and 3 % tungsten.

They noticed that in the unmodified cast iron the volume fraction of austenite was high, and carbides appeared as thick laths. An addition of 0,8 % of REM noticeably decreased the volume fraction of austenite and refined the size of its grains. The carbide laths became thinner and their morphology developed into a rosette-like shape/groupings. Heat treatment contributed to another beneficial effect on the microstructure by further reducing the austenite grain size. A similar effect, this time on the formation of graphite in grey cast iron, was noticed by the authors of papers [5 - 8], who studied cast iron after introducing cerium, yttrium or mischmetal. They noticed that the modification improved the structure by reducing the matrix grain size and graphite precipitations. G. Nandori and P. Jonas conducted research on the modification of malleable cast iron [9]. They found that even small amounts of rare earths used in the smelting process showed very good activity in desulphurization and deoxidation, and in the improvement of castability and mechanical properties. Microadditions of REM used by G. Buza [10] in the cast iron with a pearlite - ledeburite structure for the production of ductile iron improved casting properties considerably.

Rare earth metals are also known to markedly modify graphite morphology in cast iron [11]. The addition of REM and Mn was found to have a positive effect on the process of graphite crystallization by promoting its formation into globular precipitates and providing a more even distribution in the matrix. Dealing with similar issues, the authors of [12] observed that the highest concentration of cerium did not occur in the graphite phase, but at the boundaries of the graphite - matrix phases or at the boundaries of the primary structure. The contents of Ce at specific locations were dependent on the amount of Ce introduced during the inoculation process.

The search for improved abrasive properties of grey cast irons at their other mechanical properties maintained is an interesting research direction in the context of REM additives. Abrasiveness strongly depends on the material structure, which is, in turn, strongly affected by REM. This influence, however, must be balanced, because too much of REM adds whitening and brittleness. Literature review [13] helped to select the optimum proportion of REM to the mass of the base metal. The most effective content of REM in terms of the structure and properties of grey cast iron was 0,3 %.

MATERIALS AND EXPERIMENT

Grey cast iron was manufactured by remelting pig iron, steel, ferroalloys and alloying additives. Mischmetal with the chemical composition as in Table 1 was added as a modifier directly to the melting furnace. The metallurgical process was carried out in the PI35

J. Kasińska (kasinska@tu.kielce.pl, Kielce University of Technology, Faculty of Mechatronics and Mechanical Engineering Kielce, Poland
D. Myszka, Faculty of Production Engineering, Warsaw University of Technology, Poland

Table 1 **Mischmetal chemical composition / wt %**

REM	Ce	La	Nd	Pr	other
% wt.	49,8	21,8	5,5	5,35	balance

Table 2 **Cast iron chemical composition / wt %**

Material	C	Si	Mn	P	S
CI-0	3,48	1,87	0,71	0,16	0,08
CI-3 0,3 % REM	3,35	1,65	0,68	0,56	0,02

medium frequency induction furnace with a capacity of 40 kg. The castings samples with the chemical composition as in Table 2 were bars 30 mm in diameter. Specimens for abrasion resistance tests as well as strength, impact and hardness tests were cut from the central part of the bars as per PN-EN 1561:2011. The microstructure of the specimens etched with a solution of HNO3 in C2H5OH was observed using a JSM 7100J scanning electron microscope. Metallographic images were analysed using the Image J program. Standard deviation was determined for minimum 20 measurements in five randomly selected areas.

Abrasive wear tests were carried out on the Anton Paar TRB tribometer under dry friction in the ball-on-disc mode and in reciprocating motion. Test parameters were as follows: load -10N; friction path – 1 000 m; linear speeds – 0,1 m/s; test temperature - 25 + / - 1 ° C; humidity – 50 %. A 6 mm diameter ball of 100Cr6 alloy was used as a counter-sample.

RESULTS AND DISCUSSION

The addition of 0,3 % REM purify the structure of cast iron, modifies the morphology and changes the distribution of graphite from interdendritic to uniform (Figure 1), thus improving the mechanical properties of cast iron at room temperature while maintaining a similar proportion of graphite in the structure. Adding REM to the cast iron improved its tensile strength by 10 – 20 %. The impact strength was 20 % higher than that of the original grey cast iron (Table 3).

Table 3 **Mechanical properties and graphite content of CI-0 and CI-3 cast iron**

Specimen No	Hardness / HB	Tensile strength / MPa	Graphite content / %
CI-0	205	243	8,0±0,3
CI-3	199	305	8,6±0,2

Mischmetal added at 0,3 wt % provided graphite with the more developed morphology and flakes that were less sharp than those in CI-0 (Figure 1).

Distances between cementite platelets in pearlite decreased slightly to 0,55 µm in CI-0 and 0,35 µm in CI-3 at the standard deviation of 0,14 µm and 0,08 µm, respectively. REM concentration in the structure of the tested grey cast iron was visible mainly in non-metallic inclusions (Figure 2) also containing a high proportion of sulphur and oxygen. In addition, increased lanthanum and cerium contents were identified at the phase boundary between the matrix and graphite, especially in the areas where ferrite was present (Figure 3 and Figure 4).

Figures 5 and 6 show the results of tribological tests for the unmodified and REM-containing cast irons. The average coefficient of friction (out of 3 tests) was 0,59 for unmodified cast iron and 0,48 for the that with REM addition. The average linear wear was found to be 50,23 mm for unmodified and 48,61 mm for modified cast

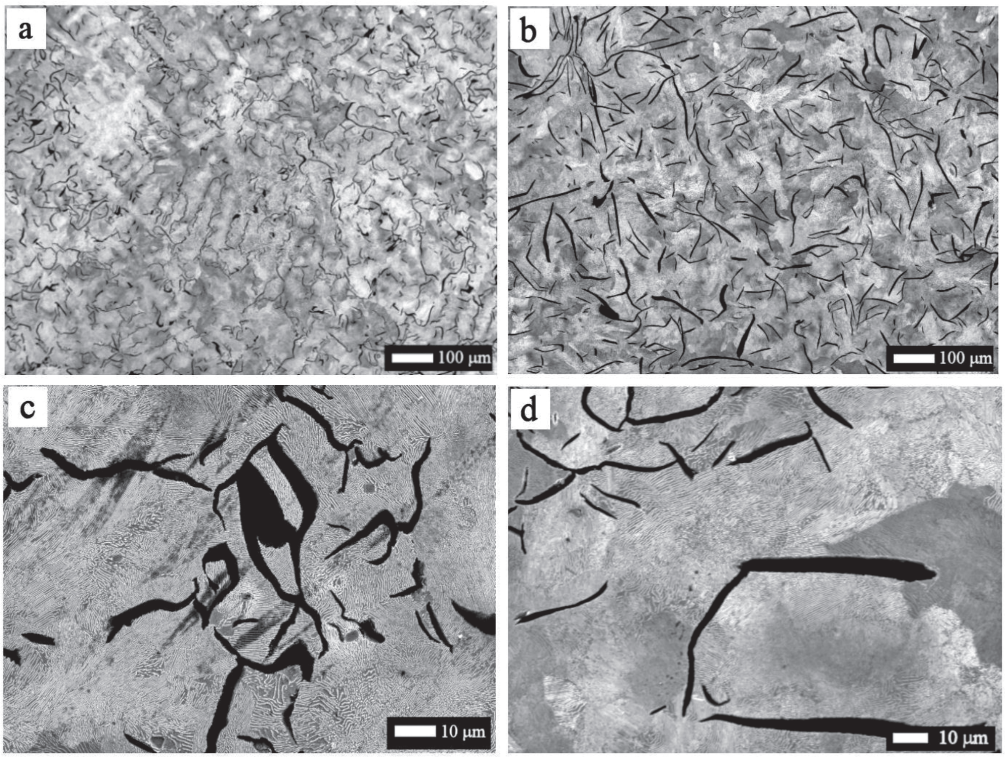


Figure 1 Cast iron microstructure and graphite morphology of CI-0 (a, c) and CI-3 (b, d).

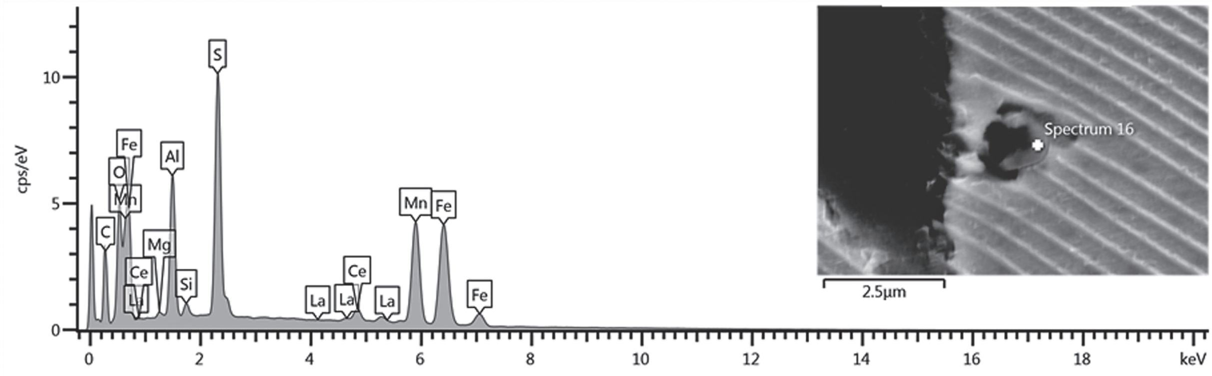
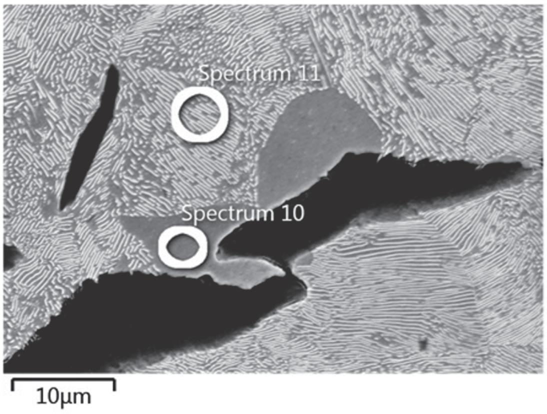
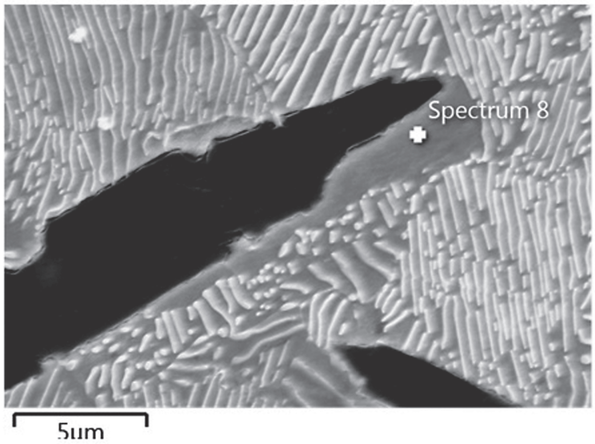


Figure 2 X-Ray analysis of non-metallic inclusions of CI-3 sample, Energy Disperive Spectroscopy (EDS)



Spectrum Label	Si	Mn	La	Ce
Spectrum 10	2,09	0,58	0,17	0,18
Spectrum 11	2,08	0,76	0,00	0,00

Figure 3 X-Ray analysis of selected elements (EDS / wt. %) on pearlitic and ferritic structure of CI-3 sample.



Spectrum Label	Si	Mn	La	Ce
Spectrum 8	2,06	0,71	0,47	0,23

Figure 4 X-Ray analysis of selected elements (EDS / wt. %) of ferritic area of CI-3 sample

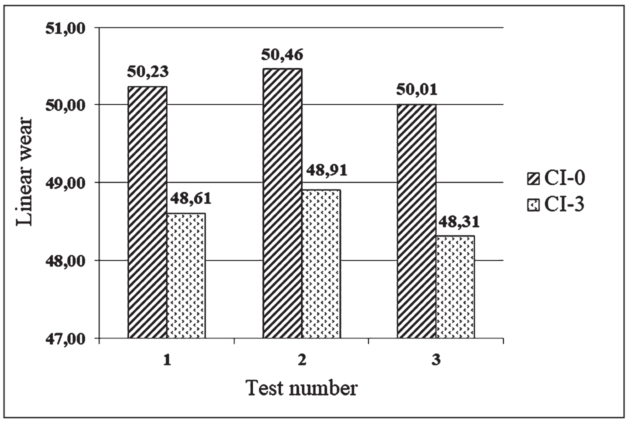


Figure 5 Average linear wear of CI-0 and CI-3 cast irons

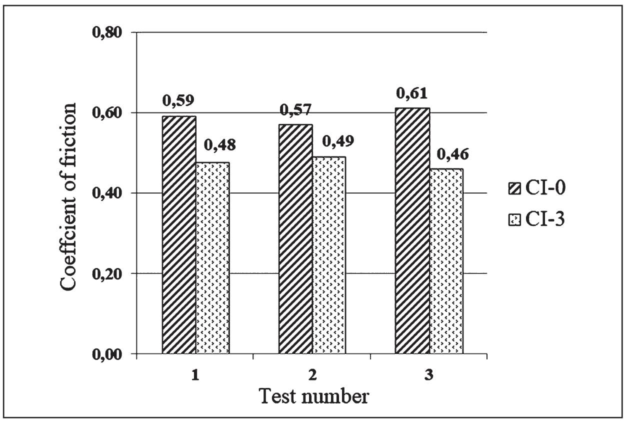


Figure 6 Average coefficient of friction for CI-0 and CI-3 cast irons

iron. The tests showed the friction coefficient reduction of more than 18 % for REM modified cast iron with a slight decrease in the average linear wear (by approx. 3 %). It can thus be concluded that the modified cast iron exhibits low friction properties.

CONCLUSION

The introduction of REM at 0,3 wt % into the feed metal altered the graphite morphology leading to a minor growth of the flakes and an increase in its content in the cast iron structure. At the same time, a change in pearlite morphology was observed as the distance reduction between the cementite plates. Changes in the microstructure contributed to the improvement of the tested mechanical properties (impact strength, tensile strength). The results of tribological tests indicate an improvement in the tribological properties of the tested friction pairs for cast iron containing REM. The friction coefficient was reduced by more than 18 %, which can be attributed to the lubricating properties of graphite.

Acknowledgments

The authors would like to thank Marek Grzybowski from the FERRUS GROUP for providing pig iron and carburiser for the melt.

REFERENCES

[1] J. Kasińska, Wide – ranging influence of mischmetal on properties of G17CrMo5-5 cast steel, Metalurgija, vol. 54, (2015) 1, 135-138.

[2] J. Kasińska, Influence of Rare Earth Metals on Microstructure and Mechanical Properties of G20Mn5 Cast Steel, Archives of Foundry Engineering, vol. 18 (2018) 3, 37-42

[3] D. Myszka, E. Skołek, A. Wieczorek Manufacture of toothed elements in nanoausferritic ductile iron, Archives of Metallurgy and Materials 59 (2014) 3, 1217-1221

[4] Gou Erjun, Wang Liping, Huang Yongchang, Fu Yunake, Effect of rare Earths and Al on structure and performance of high chromium cast iron containing wolfram, Journal of Rare Earths, vol. 24 (2006) 2, 238-242.

[5] X. Guoging, Y. Zongsen, C. E. Mobley, Soldification and structures in rare earth – inoculated gray irons, Transactions of the American Foundrymen's Society, vol. 90, (1982), 934-958.

[6] J. D. Altstetter, R. M. Nowicki, Compacted graphite iron: its properties and automotive applications, Transactions of the American Foundrymen's Society, vol. 90, Paper 959 – 970 (1982), 82-188.

[7] M. I. Onsoien, O. Grong, T. Skaland, S. O. Olsen: Effect of rare earth metals on microstructure evolutions in ductile iron, Transactions of the American Foundrymen's Society, vol. 105, Paper 97-150, (1998), 147-152.

[8] P. C. Liu, T. X. Li, C. L. Li, C. R. Loper, Study of the effect of yttrium, cerium and rare earths on the graphite morphology in heavy section ductile iron, Transactions of the American Foundrymen's Society, vol. 97, Paper 89 – 04, (1989), 11-16.

[9] G. Nandori, P. Jonas, Improvement of the quality of cast irons by alloying with rare earth metals, Banyasz Kohasz Lapok, vol. 33 (1982) 11, 241-245.

[10] G. Buza, The effect of alloying with rare earth metals on hypoeutectic cast iron, Banyasz Kohasz Lapok, vol. 27, (1976) 27, 214-217.

[11] A. Strkalj, Z. Glavas, I. Mamuzic, Microstructure and properties of silicon alloyed compacted graphite irons (CGI), Metalurgija, Vol. 59 (2020) 2, 147-149.

[12] M. V. Mozharov, A. P. Lyubchenko, Petrichenko A. M.: Microdistribution of rare earth metals in cast irons, Metal Science and Heat Treatment, vol. 15, 967-971, (1973) 11 (translated from Russian: Metallovedenie i Termicheskaya Obrabotka Metallov, (1976) 11, 42-47).

[13] Zhang Daowen, Li Zhu, Huang Ji: Effect of Rare Earth Alloy Modification on High Carbon Equivalent Gray Cast Iron of Automotive Brake Drum, Journal of Wuhan University of Technology-Mater. Sci. Ed., vol.27, (2012) 4, 725-729.

Note: The responsible for English language is Nina Kacperczak