Swift Journals

Swift Journal of Engineering and Manufacturing Technology
Vol 2(2) pp. 005-010 April, 2016
http://www.swiftjournals.org/sjemt

Original Research Article

Investigation of Some Alloyed (Sg) Ductile Irons

Khidhair Jasim

Al-Mustaqbal university collage, Babylon, Iraq

Accepted 4th April, 2016.

In this work we examined six grades of alloyed SG iron with bianitic – Martensitic and pearlitic matrix structure according to PN- 76/H83142- polish standard. The alloying elements were Ni, Mo and Cu with moderate weight percentage. The chemical compositions of tested grades and metallographic examinations, also, hardness was tested, relative values of magnetic phase also tested. Investigation results and their discussions were included in this article the result showing the effects of those alloying elements on the structure and properties of tested grades of ductile iron. The main goals of this work were to indicate the results of each test such as chemical composition, structure, hardness of alloyed SGiron, and relative magnetic phase, to increase the knowledge's dealing with that growing importance material in different applications.

Keywords Ductile iron, alloying, investigation.

INTRODUCTION

Cast iron generally is one of the oldest ferrous metals used in construction]1[. It is primarily composed of Fe,C , and Si. But it may also contains traces of S and P and they have gray color due to free graphite]2,3[. Ductile iron or SG iron was invented in 1943 and start production at (1951) with about five million ton /year . This material could contains many other alloying elements such as Ni, Cu , Cr ,Mo…etc. to get special specified properties required for applications either as cast or by heat treatment]4[The spherical shape of graphite can be obtained by (Mg) treatment .The microstructure of SG iron generally was shown in (fig1)] 5 [.Acicular matrix SG iron structure (Bainitic or bainitic – martensitic) could be obtained by alloying with certain elements with different percentages , which affect the phase transformation of SG iron and achieving the required structure by heating and cooling .

According to the investigations, different properties can be obtained by useful heat treatment]6[. Most varieties of cast iron are brittle , ductile iron has much more impact and fatigue resistance,due to its nodular graphite inoculation] 7[. In ductile iron rounded nodules inhibit the creation of crack, thus providing the enhanced ductility that gives the alloy its name]8[. An element such as copper or tin may be added to increase tensile and yield strength while simultaneously reducing ductility . Improved corrosion resistance can be achieved by replacing 15% to 30% of the iron in the alloy with varying amounts of nickel , copper, chromium or Mo .Ductile cast iron properties are changed by adding alloying elements next to C &Si, is the most important alloyant because they force C out of solution Ni is one of the most common elements because it refines pearlite and graphite structure, improve toughness, Cr and Cu are added to the ladle or to the furnace in (0.5-2.5)% by Wt to decrease chill, refine graphite and increase fluidity.

Mo is added in the range (0.3-1.0)%by Wt to increase chill and refine graphite and pearlite and increase fluidity. It is often added with Ni & Cu and Cr, to form high strength]9[. A more recent development in nodular or ductile cast iron. Tiny amounts of magnesium or cerium added to those alloys slow down the growth of graphite precipitates by bonding to the edges of the graphite planes ,along with careful control of other elements and timing, this allows the carbon to separate as spheroidal particles as the material solidifies. The properties are similar to malleable iron with higher ductility, but parts can be cast with larger sections] 10[. New research programs aimed to improve production technology, solving its problems and providing better manufacturing economies. Exchange of technical and production knowledge take place by research and new technology] 11[.

Tech. and institution Manual, millions researches through the last century of investing improvement were done in manufacturing efficiency, productivity, and capacity these required more modification in the foundry of ductile and other grey cast irons]12,13[. Through the last century more modifications were required in the foundry of ductile iron and other grey iron[14[.Metallurgical controls of (DI) production must test its chemical composition before treatment with Mg, it

**Corresponding Author:* Khidhair .Jasim, Al-Mustaqbal university collage, Babylon, Iraq
Email: Khidhair_aljuboury@yahoo.com

is important to know the S% in liquid iron, as it resists spheroidal graphite formation. The addition of Mg is required to form the spheroidal shape of graphite at a temperature about 1450 ◦C. The Mg required for that treatment range (0.25-1.0)%.] 15[.The usual elements added to promote hardenability are Ni up to 2% and Mo up to 0.75%.]16[Cu has limited solubility in molten iron i.e. below 1.5%.] 17[. Ni is added to cast iron as graphitizer , it increases the toughness of the matrix, and getting more unstable pearlite . Ni also makes it easier to heat treat to form a martensitic structure. Cu is similar to Ni in many ways, but it is stronger in pearlite promoting. At 2% Cu matrix will be 100% pearlitic. Mo is a pearlite stabilizer and promotes hardenability it is mostly used with Cu or Ni but in lower addition rate because of its segregation tendencies.[18[. Mo is added in the range (0.3-1.0)% to increase chill and refine graphite and pearlite and increase fluidity of DI. Small amount of Ni and Mo promote the formation of ferrite and increase ductility mainly with low alloying.] 19[.

MATERIALS AND METHODS

The following tests were done in this work by investigating some alloyed ductile irons of bainitic SG iron with Ni.Mo and Cu additions.

Chemical composition of tested grades of SG iron

Identification of phase transformations occurring in tested specimens of grades of baintic SG irons according to above polish standards, have melted in the melting and crystallization workshop metal testing department, in the acidic linings induction furnace in Institute of Foundry Researchs .Cracow-Poland. Chemical compositions are given in table (1).

Applications

Much of the annual production of ductile iron is in the form of ductile iron pipe, used for water and sewer lines. It competes with polymeric materials such as PVC, HDPE, LDPE and polypropylene, which are all much lighter than steel or ductile iron; being more flexible, these require protection from physical damage. Ductile iron is specifically useful in many automotive components, where strength needs surpass that of aluminium but do not necessarily require steel. Other major industrial applications include off- highway diesel trucks, Class 8 trucks, agricultural tractors, and oil well pumps. In wind power industry, nodular cast iron is used for hubs and structural parts like machine frames. Nodular cast iron is suitable for large and complex shapes and high (fatigue) loads [20[.

METALLOGRAPHIC EXAMINATION

Metallographic examination to test microstructures in the testing Workshop. Examination of casted specimens having dimensions: Ø32×60 mm, showed spheroidal graphite (SG) in an acicular matrix of lower or higher bainite or martensite, traces of carbides appear on grain boundaries in figs. (2-7), microstructures of tested grades of ductile iron were presented.

Hardness test

For more precise characteristic of the structure of casted samples (CES) from the tested grades of SG iron, hardness tests were done by Brinellmethod. The hardness numbers were at Rockwell unit. Testing were done in the workshop of strength of testing casting construction in Foundry research Institute -Cracow- Poland. Results of testing were listed in table 2.
Every result was the arithmetic mean value of six readings for CES sample using approximation given by O.L. Davies equation to calculate mean square of variation for hardness readings.

$S_x = R/d_n$

Where Sx - mean square variation, R - mean (value)
dn - coefficient depend on the quantity of equality of readings
According to O.L Davies equation:
For six readings – d6= 2.534
For four readings – d4 = 2.054
By this method mean square of (value) calculated hardness HRC: for sample CES – Sx =0.861

Relative Values of magnetic phase test

For exact identification of phases existed in the tested sample (CES), the relative quantity of magnetic phase have measured. For this purpose, apparatus type FerrikompΠ, was used. It was calibrated in such a way to give zero % reading for austenite SG iron (ZsNi 13Mn7) according to polish standards (PN-76/H-83139) without Cr, and 100% for samples of SG iron No.4 of maximum value of magnetic phase .Testing was done at room temperature (20C◦) and the results shown in table3.

RESULTS OBTAINED

The main results of this work are

1-The chemical analysis showed that all types of tested alloyed SG ductile irons are nearly free of Cr. (0.05%), low in S (0.012%) and high in C,(3.36%) and also high in Si (2.8%). With traces of Mg (0.045%) by weight %.
2-The alloying elements ranges are: Ni (2.42-4.25)%, Mo(0.01-0.82)% and Cu (0.02-1.15)%.
3-Spherical shapes of graphite appear in the microstructure matrix of all types of tested alloyed ductile irons, due to the above compositions.
4-The hardness of the tested samples of SG alloyed ductile iron were high and range between (48.34)HRC for ductile iron No.4 to (51.64) HRC for ductile iron No.6 by using the Brinell method.
5-The relative part of magnetic phase in tested samples of ductile irons ranged: between (88%) for iron No.1 and (100%) for iron No.4, which was free of austenite phase as non-magnetic.
6-The microstructures of tested irons contains acicular (Martensite ,bianite) and pearlite as shown in figs : (2-7).

CONCLUSIONS AND RECOMMENDATIONS

It was clear that the residuals of (Mg element) in the tested irons indicate that sufficient amount of that element were used to form the spherical shape of free graphite which presents in the tested irons. That was shown in the figs : (1-7). (High C% and Si%) low S% were very important in production of SG. Iron. The relatively low hardness for SG iron No.4 (48.34 HRC) was due to lower Mo and highest Ni and Cu which are promoting pearlite formation, so lowering martensitic –or Bainitic structure, which has higher hardness and strength. The presence of Mo in irons No.1 and No.2 about (0.8%) which is also pearlite stabilizer used with Ni or Cu because of its segregation tendency, promoting hardenability, refining graphite and pearlite i.e. increasing hardness and strength. The highest relative magnetic phase (100%), indicates that all austenite was transferred into pearlite or martensite which were magnetic phases , while the other tests still contain traces of retained austenite (non-magnetic) .Accordingly the structure and composition i.e. alloying elements also (C,Si, S ,Mg) % – must be controlled carefully in order to achieve the required properties and developing ductile iron production, manufacturing efficiency ,productivity and capacity. We hope that continuous researches in this field could be done for further development.

ACKNOWLEDGE

The author thanks department air condition and refrigeration, this work was supported by Al-Mustaqbal university college. And the assistance of Prof. PIASKOWISKI - ins. ODLIWNITCWA KRAKOW –POLAND -REVICES -2016

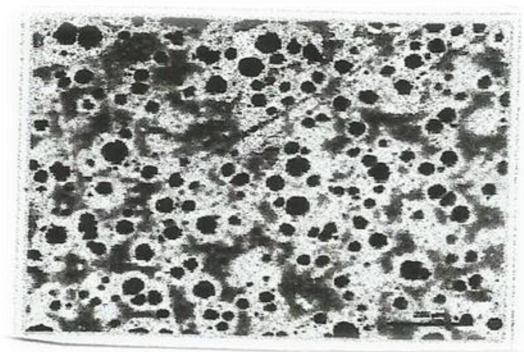

Fig.(1) ductile iron microstructure at 100× carbon islanding effect around nodules**[** 5**]**

Table.1 Chemical composition of tested grades of bainilie SG iron

SG iron grades	Elements content %									
	C	Si	Mn	P	S	Mg	Ni	Mo	Cu	Cr
SG iron No1 (ZsNi2,7Mo)	3.36	2.75	0.49	0.105	0.012	0.048	2.75	0.82	0.02	0.06
SG iron No2 (ZsNi4,0Mo)	3.38	2.58	0.48	0.107	0.012	0.047	3.86	0.77	0.03	0.06
SG iron No3 (ZsNi3,2Cu1,1)	3.34	2.78	0.45	0.105	0.011	0.083	3.32	0.09	1.14	0.05
SG iron No4 (ZsNi4,5Cu1,1)	3.56	2.82	0.43	0.043	0.013	0.031	4.25	0.01	1.13	0.05
SG iron No5 (ZsNi2,2Cu1,1 Mo)	3.56	2.88	0.48	0.095	0.011	0.041	2.42	0.068	1.15	0.05
SG iron No6 (ZsNi3,2Cu1,1 Mo)	3.54	2.88	0.45	0.095	0.012	0.042	3.25	0.067	1.14	0.05

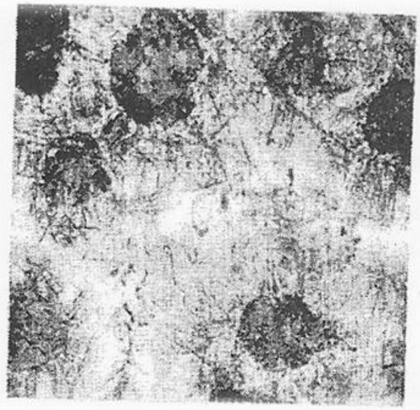

Fig.2 structure of SG iron No.1- Nital 3%-×250

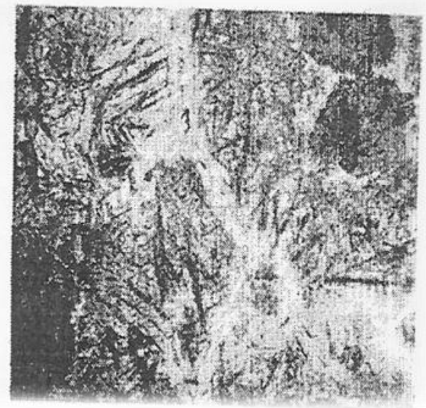

Fig.3 structure of SG iron No.2- Nital 3%-×250

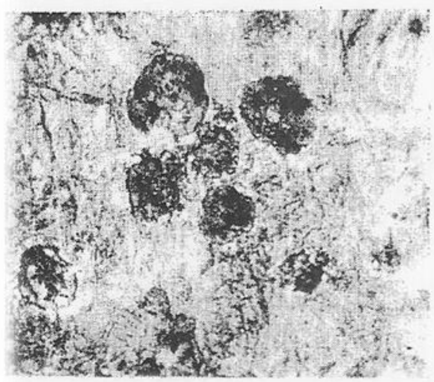

Fig.4 structure of SG iron No.3- Nital 3%-×250

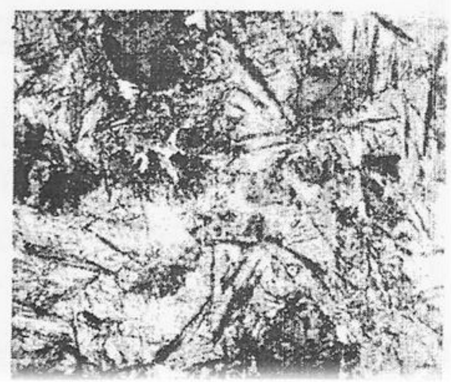

Fig.5 structure of SG iron No.4- Nital 3%-×250

Fig.7 structure of SG iron No.6- Nital 3%-×250

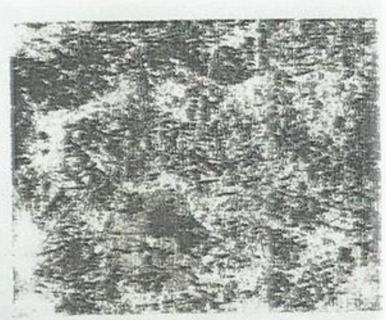

Fig.6 structure of SG iron No.5- Nital 3%-×250

Table. 2Results of hardness test (HRC) for tested grades of SG iron

Cast iron grade	Type of sample	Hardness Reading HRC					Average
		1	2	3	4	5	
Cast iron No1	CES	50.5	50.2	49.2	50.1	49.8	50.0
Cast iron No2	CES	50.0	51.3	52.1	50.7	50.7	50.96
Cast iron No3	CES	52.7	52.4	52.1	50.5	51.2	51.58
Cast iron No4	CES	47.8	47.3	48.2	48.4	50.0	48.34
Cast iron No5	CES	50.3	50.2	50.4	50.3	52.5	50.74
Cast iron No6	CES	51.0	50.1	52.0	52.7	52.4	51.64

Table. 3 Relative part of magnetic phase in tested samples from SG iron

Cast iron grade	(Relative part of magnetic phase*)% Sample CES Readings		
	1	2	Average
Cast iron No 1	88	88	88
Cast iron No 2	93	89	91
Cast iron No 3	91	90	90.5
Cast iron No 4	100	100	100
Cast iron No 5	90	87	88.5
Cast iron No 6	93	92	92.5

* As example (100%) considered part of magnetic phase in SG iron No4

REFERENCES

1. Campbell, F.C.(2008).Elements of Metallurgy and Engineering Alloys . Materials Park , Ohio ASM International . pp.453. ISBN 978-0-87170-867-0
2. Margol Gayle &David W 1992, Metals in USA Historical Building – Washigton,DC , National Park service.
3. WilliomZahner, 1995, Architectural motels- A guide to selection , specification and performance
4. Romanoff, Melvin (1968). "Performance of ductile-iron pipe in soils". Journal (American Water Works Association) (American Water Works Association) 60 (6): 645–655.
5. Yaqub ,Ejas,.Arshad , Rizwan. 2009, ME-140 WorkshopTechnology- Slide 25"(images). Air university

6. Smith, W.F. and Hashemi, J (2006). Foundations of Materials Science and Engineering,4th Edition; Mcgraws - Hill Book. pp. 28-36.
7. Modern Casting 2006Inc (http://www.moderncasting .com/archive/feature_023_01.html)
8. Ductile Iron Society, 2015, USA
9. Gillespie, LaRoux K-Wikipidia1988, Troubleshooting manufacturing process (4thed.)
10. Balvant; Kleiner, Yehuda (2003). "Protecting ductile-iron Water Mains: What protection method works best for what soil condition?". Journal (American Water Works Association) (American Water Works Association) 95 (11): 110–125.
11. WWW.ductile .org. 2015, Ductile iron Society Ductile iron – Wisconsin Dells,W1
12. Charlotie 2015, pipe and foundry Co.-cast iron
13. WWW. Ductile .org.2015, Ductile iron Society –Ductile iron- Wisconsin Dells
14. CHARL, 2015, Pipe and foundry Co. –cast iron- Tech. and institution Manual
15. Ductile iron molten metal processing -2nd .ed. AFS-USA-1986.
16. J.R. Davis1996,Classification and BasicMetallurgy of Cast Irons ASM-special Handbook casting iron effect of Ni ,Cu and Mo.on D.I.
17. AFS-KEITH, 2013, Millis – symposium on D.I.Nashville- effect of Cu TN
18. James D.,2006 Mullins- Sordmetal – Basic D.I.Alloying
19. Gillespie,1988, La RuxK.Wikipidia – Troubleshooting manufacturing process
20. Wikipidia, 2006, International the Free Encyclopedia ductile iron