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Effect of Alloying Elements on the Microstructure for Ductile cast Iron under the influence of Austempered Treatment.

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----------***ABSTRACT:*** ----------
The traditional spare parts of ductile cast iron were produced for the production of gear under casting conditions and treated with extrapolators. The results showed that the properties of the structure obtained were not thought to be the best, but should be viewed as reasonable with reasonable controls. (880 ° C) for 1 hour and then the austempering review at 200 ° C for 20, 40, 80 and 160 minutes to study the effect on microstructure and mechanical properties, tensile strength, hardness, durability and corrosion resistance .

I. INTRODUCTION

The graphite is found in the plastic iron in the shape of small balls, so that the graphite separates from the iron fuse during freezing in a similar way to its separation from gray cast iron, both having the same chemical structure. [1] Many of its products are used as an as - cast, On certain properties by adding some alloying elements for the purpose of improving resistance, durability and corrosion resistance [2]. The iron is classified according to its mechanical properties to four grades: the first grade is a high metal bonded iron and a ferritic matrix with a resistance of not less than (mm2 / Kg "24%"), and metallurgical up to (25%), while The second rank is a rectangular iron with a perlite furry floor, with a resistance to yield (mm2 / kg 32) and an elongation of not less than 8%. While the third level is a high resistance steel with a perlite surface with a resistance of not less than 2mm / Kg (35), and elongation up to 4%. The fourth level is a very high-strength, high-resistance, data-based or martensitic material produced by substrate or thermal conductivity and has a resistivity of not less than 2 mm / Kg (45) [3**.[** The production of iron iron involves three basic steps: sulfur removal, pelletization, and fertilization. For the removal of sulfur, magnesium can not be added to the iron fuse until the sulfur content is reduced to less than (0.01)%. Otherwise, magnesium sulphide will consist of slag, Surface, resulting in the lack of the amount of Mg required for the production of graphite balls. [4] The process involves the addition of sodium carbonate, calcium carbide or live lime to the iron fuse, which is intended to cause a chemical reaction between basal and sulfur **. (**Mg) is required because it is not possible to distinguish between Mg and Mg in chemical analysis, so the percentage of Mg necessary for pelletization is determined to be not less than 0.05% [6.5]. The use of Mg resulted in the generation of vapors and the volatilization of the metal, in addition to its expensive price, as well as the efficiency of the treatment (no more than 50%). Many researchers used rare elements for low process costs and lack of steam [7,8] [Inoculation] is very necessary to increase and improve the shape of pellets, in addition to preventing the formation of carbides in the sections of small fish and usually after treatment of iron before pouring the metal to prevent the decay of the vaccine alloy [9] Needed with a little fish to pollinate more than the cast The large fish to freeze faster than to expose them to Over-cooling [10]**.**

II. EXPERIMENTAL WORK:

Materials:

* Two ductile iron alloys, having different nickel content, were selected for this study
Alloy: (1): 1.3%Ni-0.3Mo and alloy.
(2): 2.6%Ni-0.3Mo. The chemical compositions of the two Alloys are presented in table (1).
*Cylindrical specimens of 150mm length x 20mm diameter.
*For more precession and more accuracy of dimensions. The melt was then poured at a
*Temperature range of (1250-1300) °C [7].
*Tensile, impact and wear test specimens were machined out from the cast cylinders. ASTM specification standards were used to determine tensile, impact and wear properties. Conventional spare gears were also cast at a final stage by sand casting method, the chemical analysis of which was the same of that of alloy (1).

Heat Treatment Cycles:

All heat treatment cycles performed during this study to produce ADI. The heat treatment cycles consisted of two stages: first, specimens were austenitized at 880ºC for (1) hr., in a muffle furnace, then austempered from austenitizing temperature to at 200ºC and 300ºC in salt bath (NaNO3 + KNO3). Holding at

these temperatures was for Predetermined times, followed by cooling to room temperature in water. The austempering times were selected to be 20, 40, 80, 160 minutes. It is of interest to mention that Quenching from austentizing temperature to the salt bath should be rapid enough to avoid any Transformation of the austenite to ferrite or pearlite.

Microstructures Examination:

*The specimens were etched in 2% nital solution (2%nitric acid + 96% ethylaecohol), examined and photo micrographic using universal inverted metallurgical optical microscope.
*Brinell hardness tests and each hardness value is the average of three readings.
*Standard tensile tests were carried out using 500 KN capacities
*Elongation's measurements were taken after exactly fitting each two parts of a broken specimen together.
*The impact testing was carried out using pendulum type impact testing machine. And the reported impact toughness for each condition was the average of three readings. Standard charpy impact specimens.

:*Wear Tests

Adhesive wear tests were carried on pin–ring type machine. The adhesive disc was stainless steel, of 50mm outer diameter and (58 RC) hardness. Wear of the specimens was measured by weight loss. Production of some gears with a definitely chemical composition and with an austempering condition that gives certain Microstructures properties as required by practical application was included at a later stage of this study.

III. RESULTS AND DISCUSSION:

Microstructure Examination:

The microstructures of cast iron used throughout this work are shown in figures (1-a, b, c, and d). Figure (1-a) illustrates the microstructure of the as-polished surface for alloy (1), whereas figure (1-c) depicts the corresponding microstructure of alloy (2). The microstructures of the as-etched conditions for alloys (1&2) are also shown in figs. (1-b) and (1-d) respectively.

Comparing figure (1-a) with that of figure (1-c) for alloys 1&2, it can be concluded that the nodule count is significantly higher in figure (1-c) as compared to figure (1-a). Such increase is fairly inherited from the potent role of Ni in enhancing the graphitization process (3% in alloy vs. 2.5% in alloy 1). The as polished structures in both figs. (1-a) and (1-c) indicated that there might have been a slight inhomogeneity of Ni which reflects some non-homogeneous distribution of graphite particles (nodules) into a ferritic / pearlitic matrix. From figures (1-b)) and (1-d) it is noticed that the amount of ferrite in the matrix of alloy (2) is significantly larger than in alloy (1), whereas alloy (1) contains mainly a pearlitic matrix along with little amount of ferrite areas around graphite nodules. The morphology of ferrite is in the form of bull-eye structure resulting from segregation of silicon and / or nickel around graphite nodule in the microstructure of alloy (1); figure (1-b). The microstructures of ADI depend on significant variables among which are: base chemistry alloying additions and heat treatment [6, 7]. The microstructures of ductile irons austempered at 200°C for different austempering time intervals corresponding to 20, 40, 80 and 160 minutes for alloys (1) & (2) are shown in figure (2). As can be seen, the matrices for alloys (1) & (2**)**consist mainly of martensitic and lower bainite. Retained austenite might not be expected. This is due to insufficient diffusion of carbon to the austenite to stabilize it, thus martensite may form during rapid cooling to room temperature and retained austenite might be slightly expected after 30 minutes, austempering time [5,9]. As the austempering time increases, the amount of martensite in the matrix decreases. In contrast, the amount of retained austenite might increase until a critical point. Such critical austempering time provides the best combination of strength and ductility. On the other hand, extended austempering time tends to enhance the bainitic transformation and hence, the amount of retained austenite decreases subsequently with increasing the austempering time until a definite point i.e. the onset of second stage austempering [11] .The presence of carbides are not beneficial in ADI since they are inferior to ductility and impact toughness . This type of bainitic structure is found in figure (2) and may provide ADI with higher strength and a relatively lower elongation [4] corresponding to ASTM standard grades [12]. The Microstructures of ductile irons austempered at 300ºC for different austempering time intervals are shown in figure (3). The matrix structure is expected to comprise upper bainite, **,** retained austenite, and martensite. The apparent amount of transformed upper bainite increases by increasing the austempering time. At shorter austempering time, untransformed austenite formed martensite by subsequent quenching**.** With longer austempering time, martensite disappeared due to the increased stability of the untransformed austenite, which is enriched by carbon. This carbon is rejected from ferrite due to the high silicon content of the ductile cast iron. The formation of carbides will be suppressed**.** A similar result was reported in other findings [2]. This treatment provides also high strength and higher elongation corresponding to ASTM standard specifications [8]. At short austempering time, the martensite was observed for alloys (2) & (1) until 30**.**

Wear Resistance:

The resistance to adhesive wear was determined for alloys (1) & (2) in the austempered (at 200ºC & 300ºC) condition. The results obtained are illustrated in terms of relative weight loss vs. austempering time. Generally it has been reported [8] that ADI exhibit significant wear resistance as compared to ductile Iron. In this work, the weight loss vs. austempering time profile for alloys (1) & (2) is the same for both austempering temperatures(200ºC & 300ºC). There is an initial steady increases in weight loss as austempering time increases, followed by a decrease then the weight loss continues to increase again. The only change between the austempering temperatures is the critical austempering time after which the weight loss reaches a minimal steady state(30-120min. at 300ºC & 160 min. at 200ºC) for alloy (1) and (80-160 min. at 200ºC & 60-120 min. at 300ºC for alloy (2). The wear resistance of ADI is explained in view of both microstructurals of the alloys after austempering. However, it is interesting to notice that the peaks in weight loss are associated in the peaks of the elongation percentage curve.

IV. CONCLUSIONS:

1- Austempering treatment at 200ºC fulfills the production of ADI of high strength, while austempering at 300ºC produces ADI with high ductility.

2-Austempering at 300ºC for Ni-Mo alloyed ductile irons produces probably due to molybdenum segregation in cell and / or grain boundaries.

3-The emergence of multi peaks upon austempering of Ni-Mo alloyed ductile iron is a point that needs much more investigation.

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TABLES, FIGURES & PHOTOGRAPHS

Table (1): Chemical Composition of Ductile Irons Used for Austempering

Al	Cu	Cr	P	S	Mg	Mn	Mo	Ni	Si	C	Chemical Element %
0.012	0.13	0.04	0.004	0.022	0.050	0.22	0.29	1.4	2.61	3.4	Alloy 1
0.011	0.15	0.05	0.039	0.023	0.071	0.20	0.3	2.3	2.64	3.5	Alloy 2

Table 2 the average mechanical properties of the as-cast alloys

Properties	Alloy (1)	Alloy (2)
Tensile Strength (Mpa)	571	544
Yield Strength (Mpa)	369	351
Elongation (%)	3.7	2.6
Hardness (BHN)	270	252
Notched Impact strength (Joule/cm²)	14	13.5

Table 3 Comparison between the obtained mechanical properties of as cast DI, ADI gears and that of replaced forged steel gears.

Properties	As cast	ADI gears	Steel gears
(Tensile Strength (Mpa)	605	790	1081
(%) Elongation	13	6.6	11.5
Hardness (BHN)	205	284	474
(Impact Toughness Joule)	87	70	41

Table 4 Relative wear resistance of ADI gears

Wear Properties	G1		G2	
	ADI	Steel	ADI	Steel
Original weight (W)	298	313	212	244
Weight after loading for120 hours on the machine (W)	285		210	
Relative weight loss AW/W	0.030 936		0.01905 73	

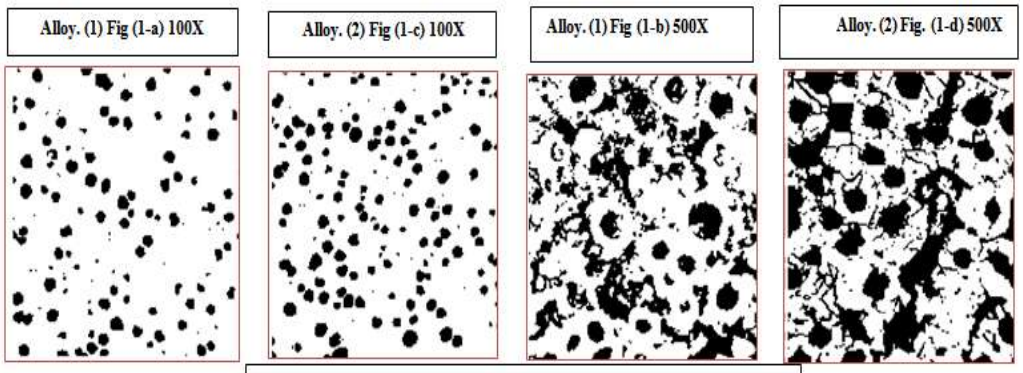
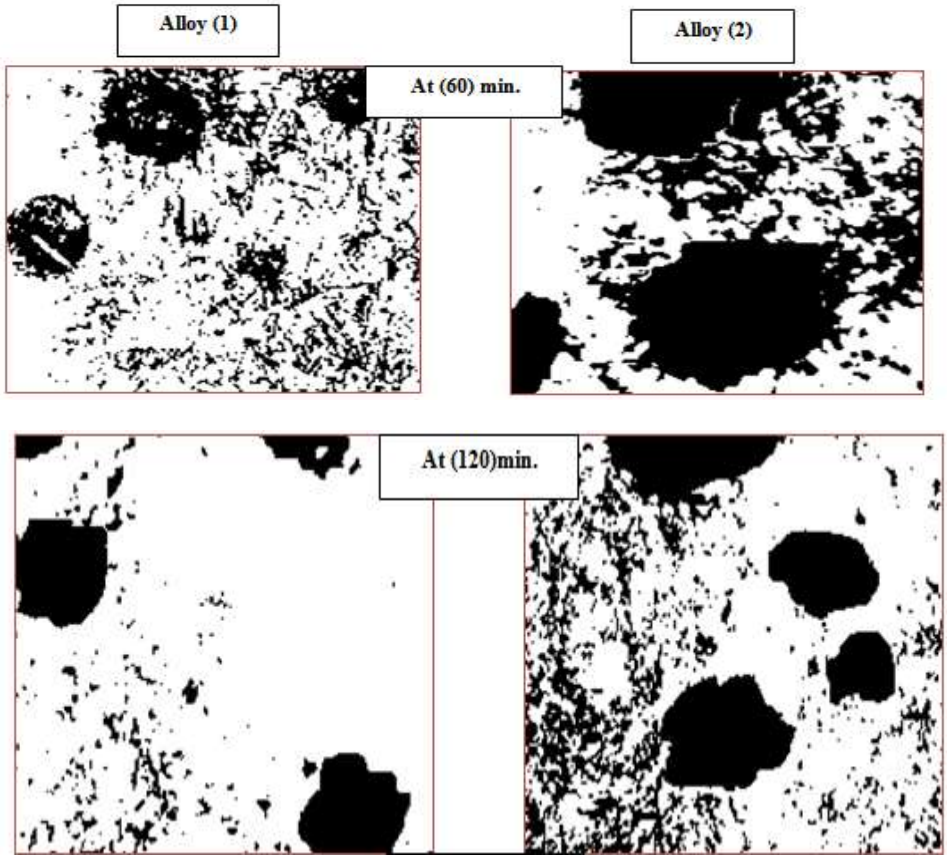


Fig.1 The microstructure of both alloys (1) & (2), prior to and after etching



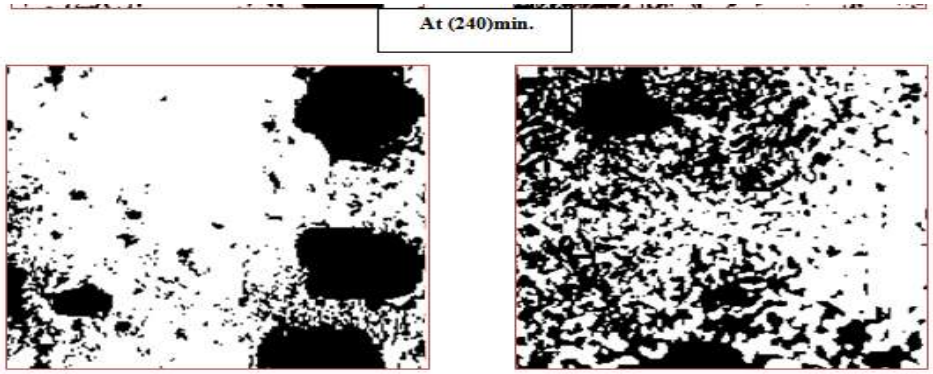


Fig.2 Microstructure change of ductile iron austempered at 200 °C for different austempering timentervals, upon austenitizing at 880°C for 60min., 500X

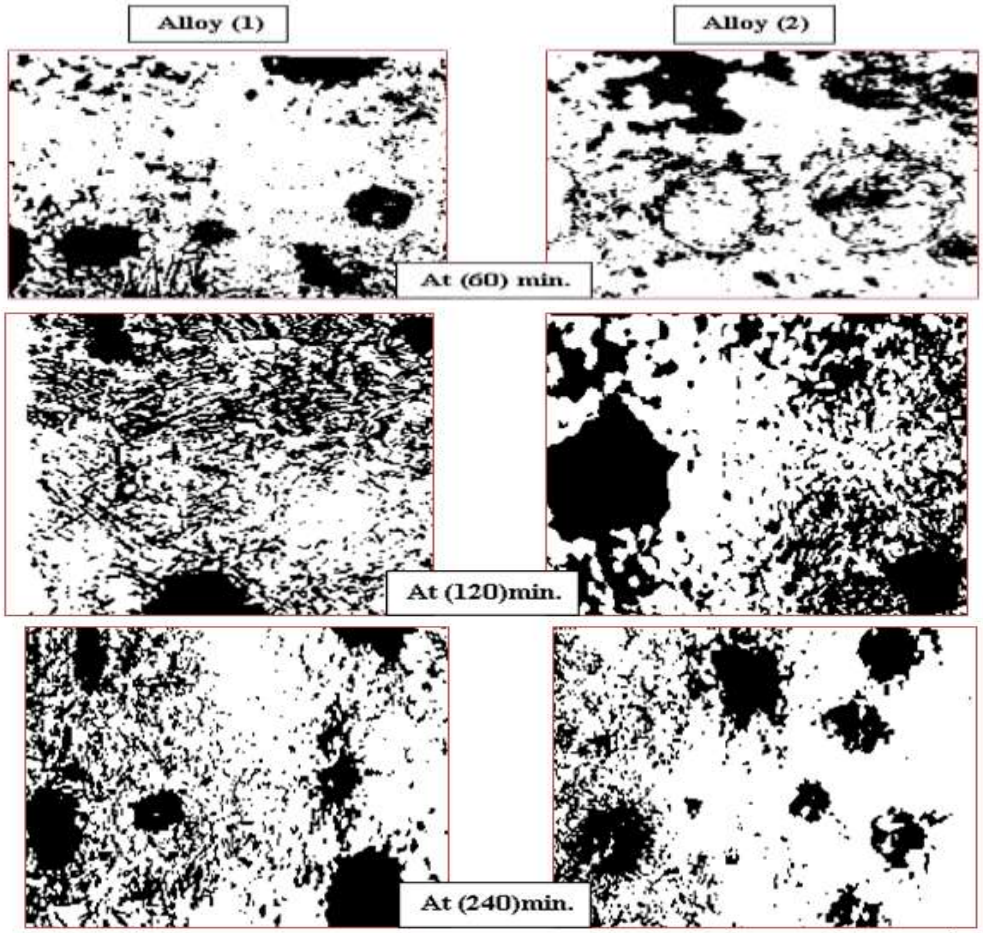


Fig. 3 Microstructure change of ductile iron austempered at 300 °C for different austempering time intervals, upon austenitizing at 880 °C for 60min., 500X.

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