Effect of Carbon Equivalent Percent on Properties of High Nickel Austenitic Ductile Cast Iron.

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Abstract:

The effect of percent carbon equivalent (%CE) ranging from 3.51 to 5.04 of austenitic ductile cast iron on microstructure, hardness and tensile properties has been investigated. Heats were designed and prepared to satisfy the required range. The matrixes of all heats are austenitic. The ultimate tensile strength, yield strength, elongation percent and hardness Vickers were obtained. In other hand, the producing of austenitic ductile cast iron of the given range will allows to study the possibility to produce standards hardness test pieces and standard masses which used in wide range in the field of force calibrations.

1- INTRODUCTION

Austenitic ductile cast irons are a series of nickel cast irons that contain nickel from 18 up to 36 weight percent of , and have been treated with magnesium to bring about the formation of nodular graphite[1-3]. It is contains sufficient nickel to produce an austenitic matrix structure similar to that of austenitic stainless steel. These irons have tensile strength ranging from 3867 MPa to 5624 MPa , elongation from 4 up to 40% and Brinell hardness number ranging from 1110 up to 1710 MPa [3]. These high – nickel alloyed ductile cast irons are made in a number of different compositions to produce the desired properties. While conventional foundry practices are used in the production of Ni – resist ductile iron castings, special precautions, not normally used, must be

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taken into considerations. Treating practices, pouring temperature and gating practice must be modified considerably from those used in conventional ductile iron production. For this reason, design engineers and Ni-resist ductile cast iron producers should review proposed casting designs if minimum cost and maximum product reliability are to be obtained [1-3]. Numerous data have been published about mechanical properties and microstructure of Austempered ductile cast iron [1-13] . However, most of recent researches focused on studying and development of Austempered ductile cast iron [9-12]. Few researchers were interested in studying the properties of austenitic ductile cast iron [2,3 and 5], but with percent carbon equivalent equal to 4.3. The present authors are interested in producing austenitic ductile cast iron as cast with percent carbon equivalent ranging from 3.51 up to 5.04. Microstructure, tensile and hardness properties of this range were investigated. A lake of information do exist in the significant area. .

2. Experimental Procedures:

Heats were prepared in 90 kg , high frequency (1000 Hz) induction furnace using charges consisting of low S, low Mn and low P pig iron (Sorel metal) and steel scrap. The chemical composition of these raw materials is listed in Table 1. Carbon equivalent calculations for high Nickel alloyed ductile cast iron are made according to formula **[3]**:

$$\mathbf{C.E = C\% + 0.33\ Si\% + 0.047\ Ni\% - 0.0055\ Ni\% * Si\%}$$

Desulphurisation procedures were not essential since the S content of raw materials was within the permissible range. The heats were heated to 1773- 1823 K. Magnesium treatment and inoculation was performed using sandwich technique [2,3 and 13]. The ferrosilicon alloy containing 10% Mg was used in the spheroidsing treatment. The heats were inoculated with 0.5 mass% of the charge (FeSi alloy 65% Si). The grain size of inoculant used ranged from 1.5 to 3 mm. Pure Nickel was melted with raw materials to get austenitic ductile cast iron as cast. Table 2 lists the chemical composition of all heats involved in this study. The melt was poured at a temperature ranged from 1620 to 1640 K, into two different moulds to produce specimens for both chemical analysis and tests. Half inch Y block sand mould was used as shown in Fig 1. Standard metallographic techniques were conducted on the examined samples [5] . Chemical etching was performed by swabbing the samples with Nital (5% nitric acid and 95% alcohol) for about 12 seconds [4, 5, 11].

Indentation hardness Vickers tests were carried out at room temperature 25 C°(300 K) using universal hardness tester (Otto Wolpert Werk) . Square based diamond indenter having an angle of 136° , 125 kg_f weight and 15 seconds duration of weight application was used in hardness test.. Tensile test was done according to ASTM (A370-2002). Specimens were machined to 5 mm diameter and 30 mm gauge length. Tests were conducted on Instron universal testing machine connected with computer to draw stress strain diagrams and recording ultimate tensile strength, yield strength and elongation. The tensile tests were performed at room temperature at strain rate 6 X 10^{-5} up to fracture.

Table 1 Chemical composition of the raw materials used in present study.

Raw materials	Composition %					
	C	Si	Mn	S	P	Fe
Sorel metal	4.0	0.1	0.1	0.02	0.03	bal
Steel scrap	0.16	0.15	0.6	0.02	0.03	bal
Ferrosilicon	0.0	65.0	0.0	0.0	0.0	bal
Carboriser	100.0	0.0	0.0	0.0	0.0	0.0

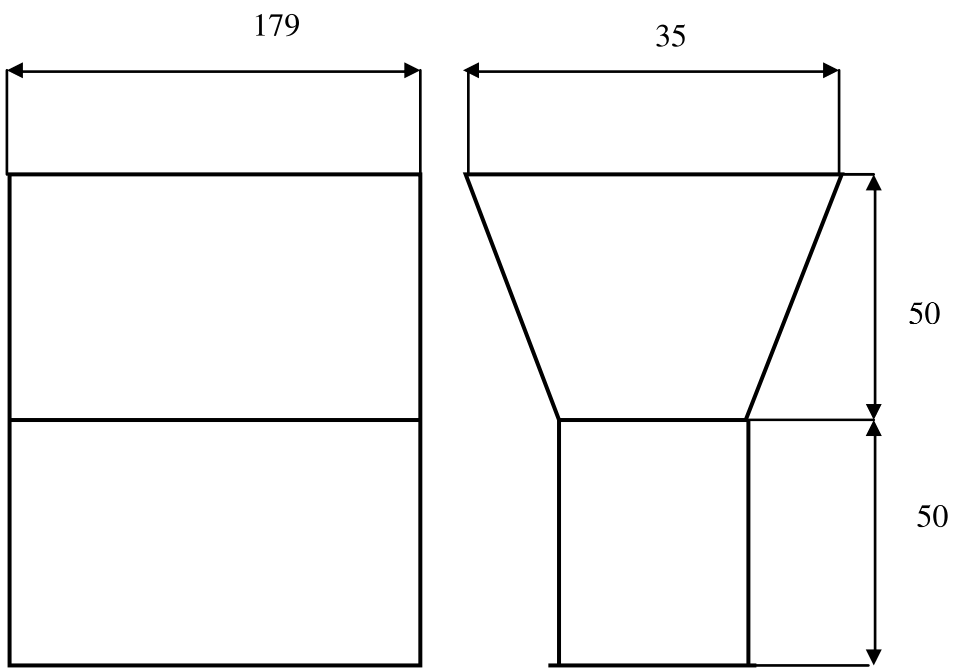


Fig. 1 Schematic of $\frac{1}{2}$ inch Y block, dimensions in mm

Table 2 Chemical composition of all heats

Heat No.	Composition %				
	C	Si	Ni	Mn	Mg
1	2.11	2.12	19.77	1.4	0.043
2	2.31	2.07	19.44	1.4	0.041
3	2.53	2.11	19.41	1.4	0.045
4	2.71	2.08	19.70	1.4	0.050
5	2.95	2.12	19.54	1.4	0.045
6	3.16	2.14	19.41	1.4	0.053
7	3.29	2.08	19.52	1.4	0.048
8	3.42	2.16	20.02	1.4	0.059

3. Results and discussion

3.1 Production of austenitic ductile cast iron having different %CE

In the present investigation, successful trails have been achieved to obtain austenitic ductile cast iron having different %CE ranging from 3.51 up to 5.04. Table 3 lists the nominal and actual %CE for all heats, the first four heats were hypoeutectic, the fifth heat was at eutectic and the last three heats were hypereutectic.

3.2 Microstructure

Fig 2 shows the as polished microstructure of the produced austenitic ductile cast iron . It is clear that , the microstructure consists of spheroids (nodules) of graphite embedded in a single white matrix: the white matrix reflects the unetched conditions of austenitic ductile cast irons. It can be seen from fig. 2 that the variation of %CE does have a pronounced effect on nodules characteristics of austenitic ductile cast iron. Typical photos of austenitic ductile cast iron microstructure of etched specimens of all heats are shown in Fig. 3. Generally speaking, the microstructure of all heats from 1 to 8, consisted of graphite-nodules embedded in austenitic matrix. Austenitic ductile cast irons must contain sufficient amount of nickel to produce an austenitic matrix similar to austenitic stainless steel [5] . On the other hand, %CE of standard types was about 4.3 according to ASTM A439. In this study, successful production of austenitic ductile cast irons with %CE less than and more than 4.3 has been achieved.

Table 3 Nominal and actual %CE for all heats.

Description	Nominal %CE	Actual %CE
1	3.50	3.51
2	3.70	3.69
3	3.90	3.91
4	4.10	4.10
5	4.30	4.34
6	4.50	4.55
7	4.70	4.67
8	4.90	5.04

Fig. 2 As-polished microstructure of austenitic ductile cast iron with different %CE ranging from 3.51 to 5.04.

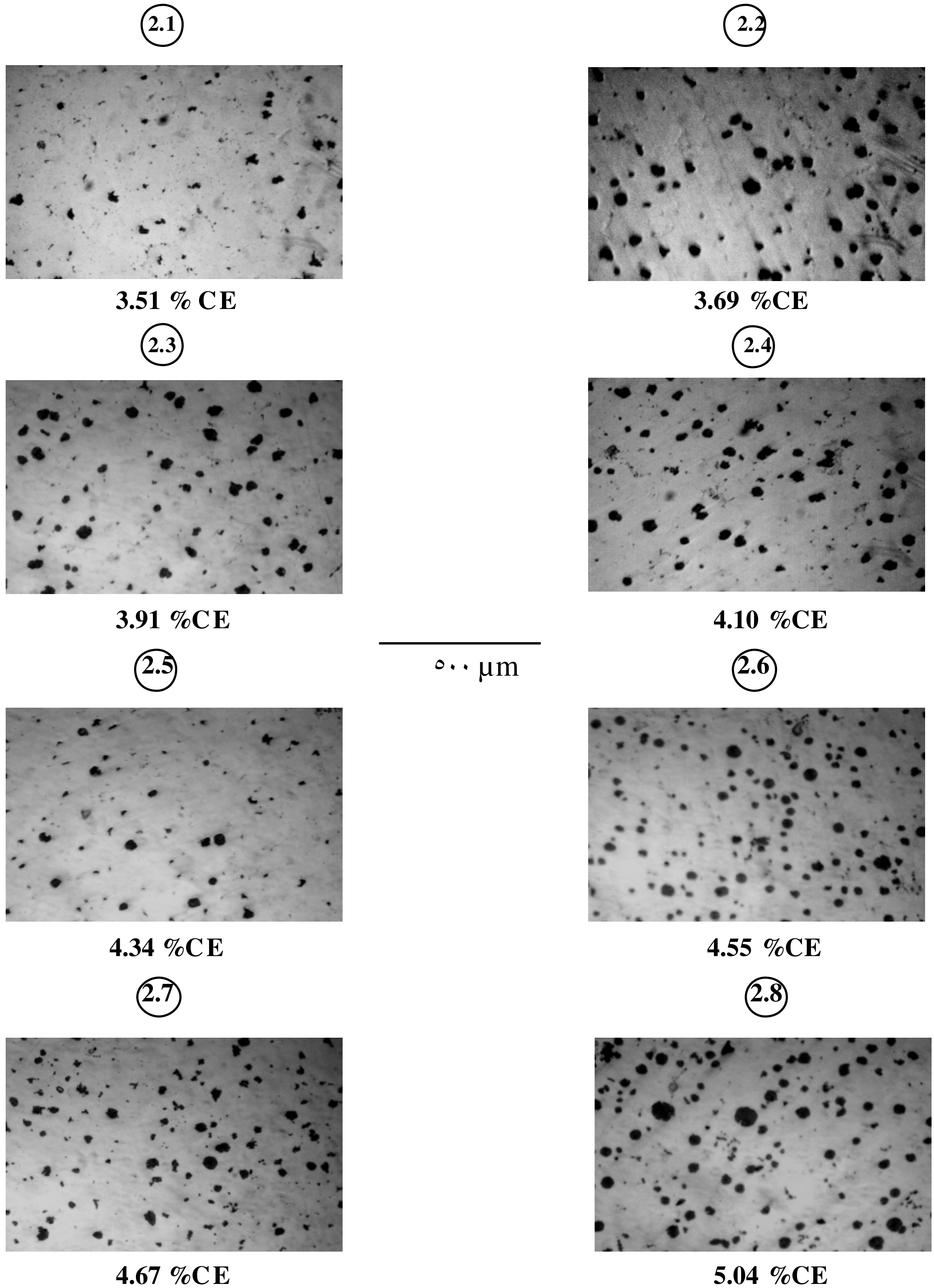
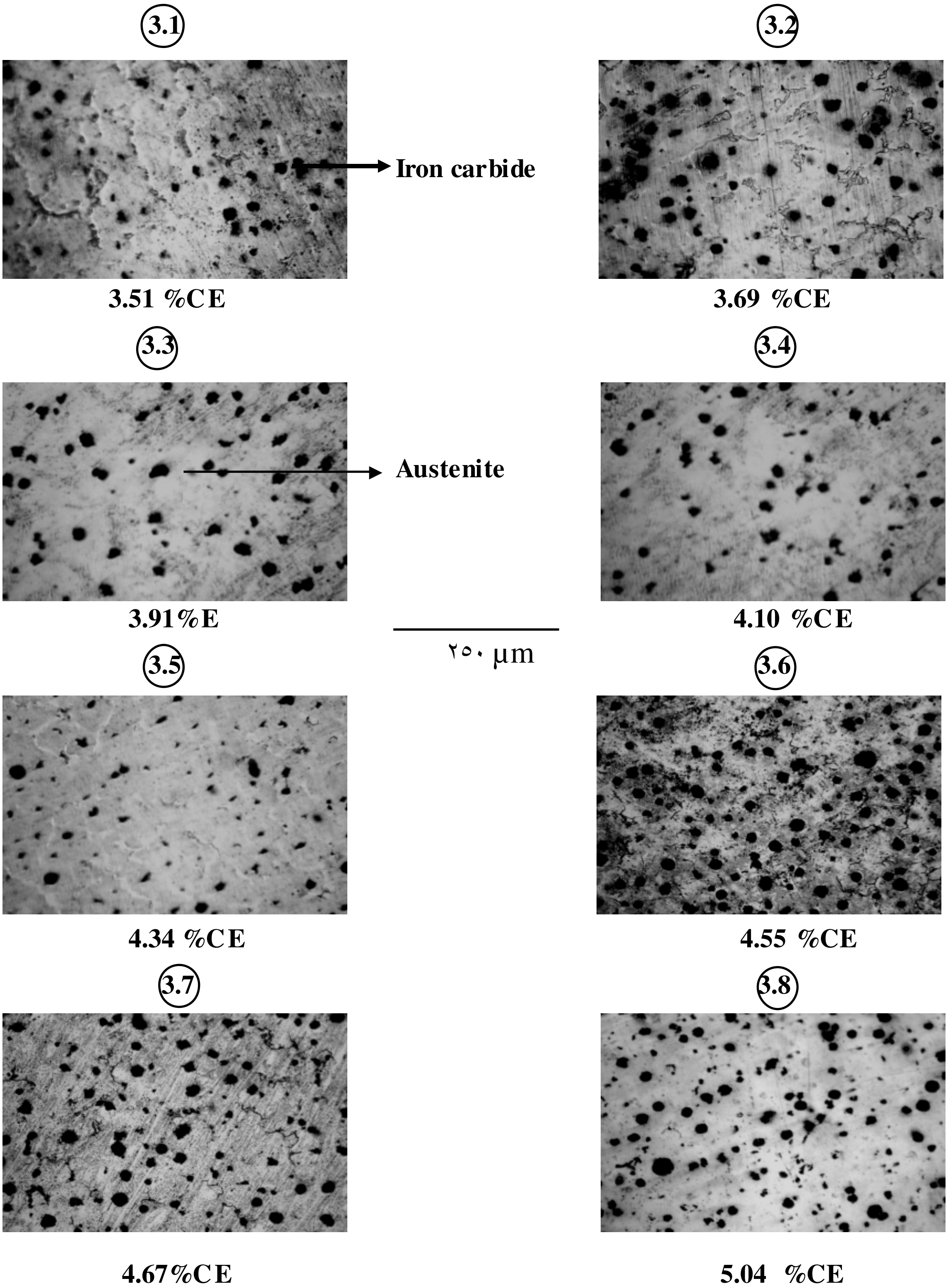


Fig. 3 Effect of Variation of %CE, ranging from 3.51 to 5.04, on the microstructure of austenitic ductile cast iron etched with 0.5 nital.



3.3 Hardness

Fig. 4 shows the influence of the %CE on the hardness values (Vickers) on the austenitic ductile cast iron used in the present study. The hardness increase gradually , as the %CE increase from 3.51 to 4.1 . this increase may refer to the increase of %C with increasing of %CE. However, the hardness values of at this range was between Hv 1670 to 1720 MPa which was at the same range of standard grades of austenitic ductile cast iron according to ASTM A439 [5]. Although hardness HV drastically decreased to a value of 1520 MP near eutectic composition, it has raised again for %CE of 5.04 to 1648 MPa, which was compatible with standard grades of austenitic ductile cast iron [5]. The increasing hardness values may be due to formation hard phases of carbides, except at 4.34 %CE, the hardness was minimum value, this may be due the behavior of nodules characteristics at eutectic point.

cast iron with different %CE ranging from 3.51 to 5.04.

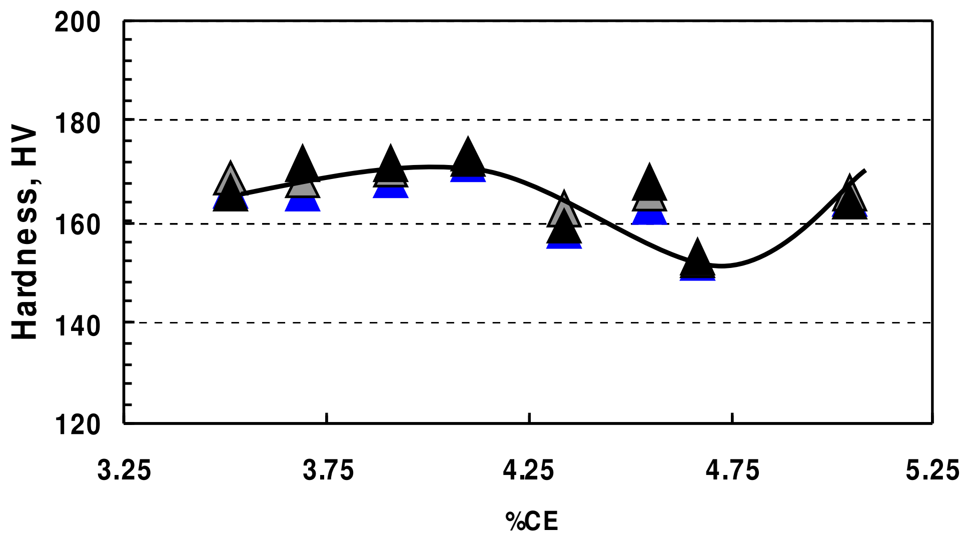


Fig. 4 Effect of Variation of %CE on Hv hardness of austenitic ductile **iron.**

3.4 Tensile properties

Fig. 5 delineates the influence of variation of %CE on the ultimate tensile strength. The curve show that, as %CE increase from 3.51 to 5.04, ultimate tensile strength (UTS) decrease. This decrease in UTS may refer to increase of the volume fraction of of softer phase with increasing the %CE (Austenite) as shown in Fig. 3. Pan et al. [7] showed that UTS of ductile cast iron is almost constant at %CE ranging from 4.2 to 5.13 which may agree with our test results in this range. The effect of %CE on UTS of standard types of austenitic ductile cast iron was concluded in ref. [5] as : UTS decrease with the increase %CE. Grade D5s of 3.16 % CE has UTS of 449 MPa, and grade D3 of %CE 3.32 has UTS of 379 MPa. However, the values of UTS of the present study ranging from 382 to 739 MPa which are compatible with the values of standard grades [5].

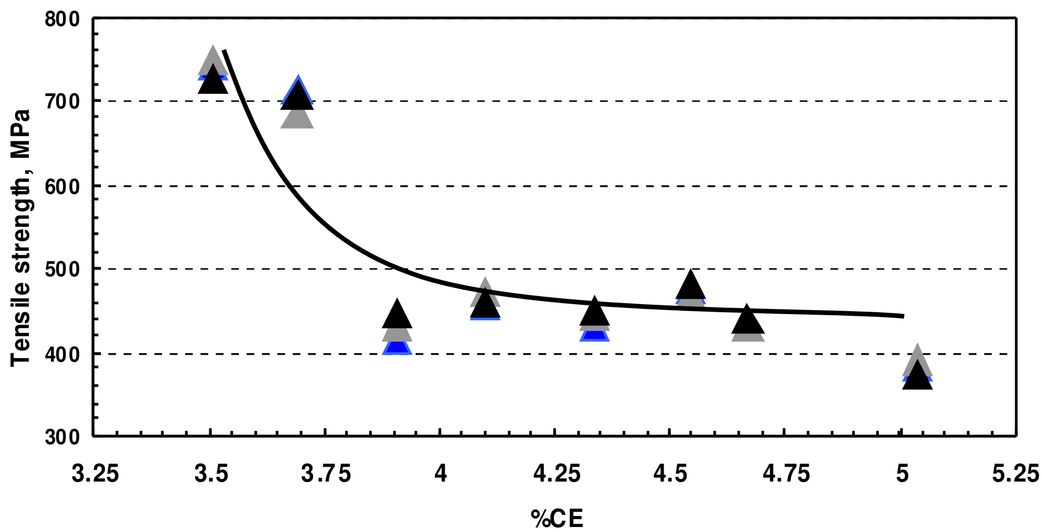


Fig. 5 Effect of Variation of %CE on UTS of austenitic ductile cast iron with different %CE ranging from 3.51 to 5.04.

Fig. 6 shows the effect of %CE on yield strength of austenitic ductile cast iron of %CE ranging from 3.51 to 5.04. The curve showed, three different behavior. The first shows a little decrease of yield strength at %CE ranging from 3.51 to 4.1 which may be due to increase of soft phase of austenite as shown in Fig. 3 . The second increase gradual from 4.1 up to 4.7 %CE, which may be due to little increase of volume fraction formation of harder phases of carbides (Iron carbide) as shown in Fig. 3. The sudden decrease at %CE of 5.04 may be due to the approximately fully austenitic phase as shown in Fig. 3-8. . Standard types of austenitic ductile cast iron have yield strength raging from 183 MPa to 207, The obtained yield strength of the present study ranges from 204 MPa to 270 is higher than that.

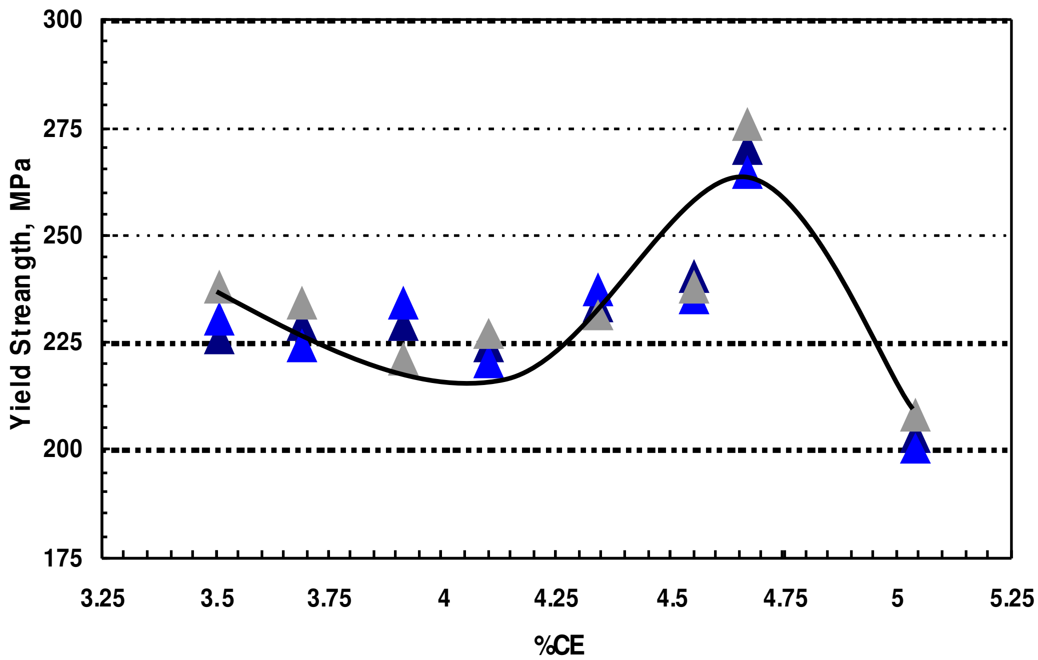


Fig. 6 Effect of Variation of %CE on yield strength of austenitic ductile cast iron with different %CE ranging from 3.51 to 5.04.

3.4 Elongation

Fig. 7 shows the effect of %CE ranging from 3.51 to 5.04 on ductility. The curve shows that, the % elongation was increased with **the increase** of % CE. . The increase of % elongation with increasing %CE may be due to : (i) Increase of volume fraction of softer phase (austenitic). (ii) Gradual improving in nodule characteristics, such as increasing nodule count and nodularity [2-7] . The values of elongation %of this study ranging from 7.5 to 18 %, on the other hand the elongation of standard types were 6 to 20% at % CE ranged from 3.51 to 5.04.

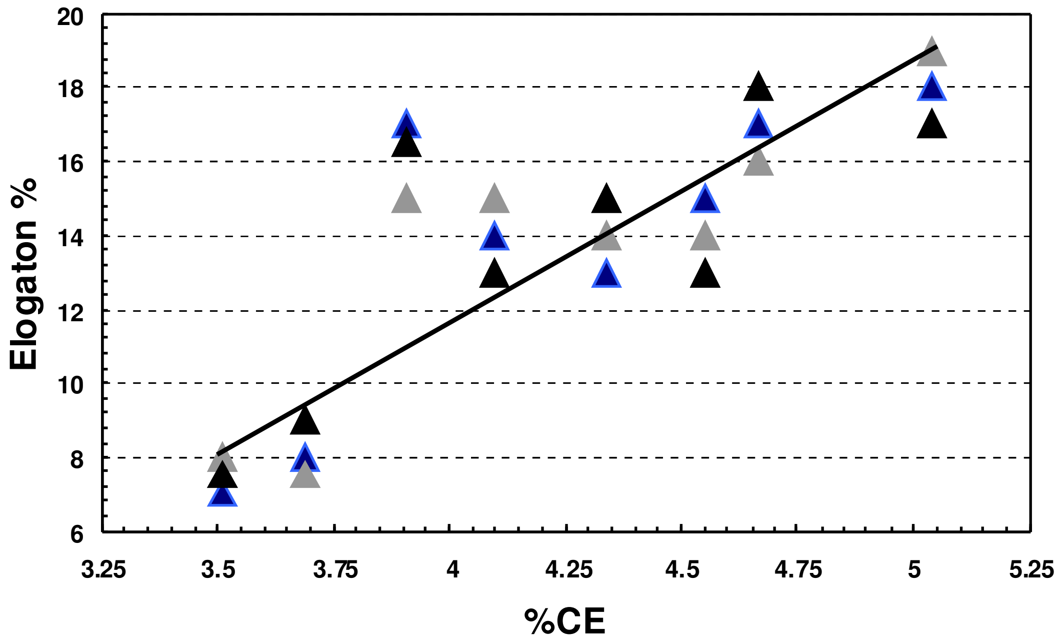


Fig. 7 Effect of Variation of %CE on %elongation of austenitic ductile cast iron with different %CE ranging from 3.51 to 5.04.

Table 4 summaries the effect of % CE on tensile, elongations and hardness properties of austenitic ductile cast iron with %CE ranging from 3.51 up to 5.04 of the present study.

TABLE 4 Effect of %CE on tensile, elongation and hardness properties

Heat NO.	%CE	HV, MPa	UTS, Mpa	Yield, Mpa	% Elong.
1	3.51	1670	739	231	7.5
2	3.69	1685	701	229	8.2
3	3.91	1702	431	228	16.2
4	4.10	1724	461	224	14.0
5	4.34	1601	441	234	14.0
6	4.55	1656	475	238	14.0
7	4.67	1524	437	270	17.0
8	5.04	1648	382	204	18.0

4. Conclusions

1. Production of austenitic ductile cast iron having percent carbon equivalent ranging from 3.51 to 5.04 has been successfully achieved.
2. The Hardness of austenitic ductile cast iron has maximum value at %CE 4.10 and minimum value of at %CE of 4.34 (eutectic point).
3. The effect of %CE on UTS showed inversely proportional between the variation of %CE with UTS.
4. The tensile least value of yield was at % CE of 4.34 (eutectic point).
5. %CE of austenitic ductile cast iron was directly proportional with elongation%

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