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Heat Treatment Studies for Improving Solution Strengthened Ferritic Ductile Iron Cast Material EN GJS 500 – 14

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Abstract

In this study, the solution strengthened ferritic ductile iron cast material EN-GJS-500–14 has been produced and characterized both by microstructurally and mechanically. Also, different heat treatments as water quench, air quench, furnace cooling, and austempering in the salt bath have been applied. The comparison of microstructures, hardness, and tensile properties have been made in order to find the best way to improve mechanical properties. By this way, the new material EN GJS 500 – 14 will have more chances for replacing conventional grades of ductile iron. The results will also guide to other the solution strengthened ferritic ductile iron grades improvement.

1 INTRODUCTION

Ductile cast iron has been used in extensively structural applications in the automotive, agricultural, and construction equipment industry due to its properties as; high tensile strength, good wear resistance, high ductility, low melting temperature and shrinkage, the high fluidity, and cost-effective way to produce near net shape components. The ductile cast iron is known as a material that has mechanical properties as good as steels and has ease of manufacture of cast irons. Meeting the demands that designers make of a component is a special challenge for the caster. Increased strength and breaking elongation enable the designer to ensure a light component with high functionality. [1] The silicon solution-strengthened ferritic ductile cast iron has recently become widely used as a structural material [2], and its tensile strength has been specified as being up to 450–600 MPa in EN1563:2011. By increasing the silicon content of 3.0–4.3% solution-strengthened ferritic ductile cast iron, the as-cast matrix structure is a single ferrite phase and the tensile strength is increased to 450–600 MPa by silicon solid-solution strengthening. And also, the elongation at rupture values increased from 10%, 7%, and 4% to 18%, 14%, and 10%, respectively. [3,4,5,6,7]

Heat treatment is an efficient way to improve material properties, and this new grade ductile iron is also heat treatable. But there are some constituents participating in the transformations exits in only a very small volume of the iron structure. These constituents include pearlite/austenite in the temperatures above Ac_1. However, pearlite can participate in the grain boundaries, where it has an important influence on the mechanical properties. Heating the ductile iron above the Ac_1 does not influence mechanical properties, as only traces of pearlite are removed. Holding the middle silicon ductile iron at temperatures above the Ac_1 causes carbon to dissolve in the grains of iron-silicon solution. After cooling, the iron has higher tensile strength but lower impact strength. [8,9]

2 EXPERIMENTAL STUDY

In order to determine the mentioned properties, some heat treatments performed on specimens with EN GJS 500-14 S.S.F.D. Iron material, Y shaped casting test block poured with a serial production part in same runner system.(Figure 1) The basic analyses of iron were selected as C: 3.25%; Si: 2.35%; Mn: 0.20% due to previous trials and literature. A cylindrical sample that has dimensions Ø20 and H:20 mm. Tensile test specimens have been machined out from the bottom side of the Y shaped test block.(Figure 2) For each heat treatment experiment, three specimens prepared and tested.

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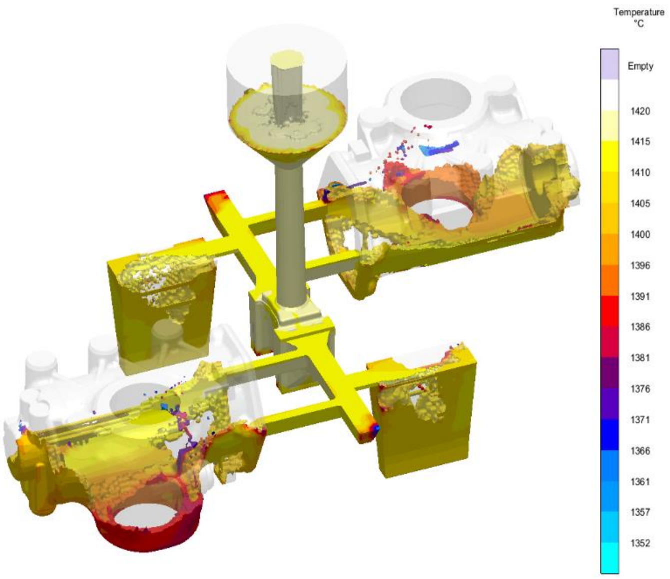

Figure 1. Y shaped casting test blocks in serial production part runner system

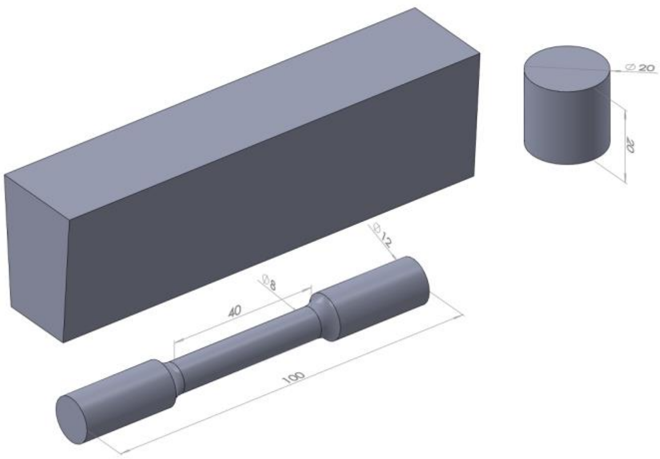

Figure 2. Tensile Test, Hardness & Microstructure Specimens

3 RESULTS

In first step of heat treatment trials after austenitizing 1hr at 950 °C; water quench, air quench and cooling down in the furnace have been performed. The microstructural and the mean hardness results are presented in Table 1.

Table 1. First Step Heat Treatment Hardness & Microstructure Results

Property/Cooling Condition	Microstructure	Hardness (HB)
As Cast	*Ferritic*	*205*
Water Quench	*Martensitic*	*350*
Air Quench	*Pearlitic*	*250*
In Furnace	*Ferritic*	*182*

The tensile tests have been applied according to to EN 1563:2012 standard. The mean results of three specimens presented in Table 2.

Table 2. First Step Heat Treatment Tensile Test Results

Property / Cooling Condition	As Cast	In Furnace	Air Q.	Water Q.
Elastic Modulus MPa	3122	3419	3694	3545
Yield Strength MPa	458	423	629,5	476
Tensile Strength MPa	552	494,5	810	488
ElongationA5 %	15,7	19,45	4,2	0,8

For the second step of heat treatments, austempering process has been tried with austenitizing 1 hr at 950 °C, and austempering 400°C in salt bath (KNO_3 - $NaNO_2$) with 5, 15, 30, 60, 90, and 120 mins. respectively. A cylindrical sample which has dimensions Ø20 and H:20 mm and three tensile test specimens have been machined out from the bottom side of Y shaped test block. The mean hardness and tensile test results of three specimens were presented in the Table 3.

Table 3. Second Step Heat Treatment Hardness & Tensile Test Results

Sample / Property	Hardness (HB)	Yield Strength (N/mm^2)	Tensile Strength (N/mm^2)	Elongation (%)	Austempering Time (min)
As Cast	205	458	552	15,7	--
Sample#1	540	709	953	0,62	5
Sample#2	465	730	1425	2,64	15
Sample#3	463	1051	1464	4,07	30
Sample#4	402	1005	1248	2,33	60
Sample#5	405	1042	1299	4,24	90
Sample#6	410	1011	1227	4,46	120

4 CONCLUSION

The results showed that all fast cooling conditions increase; the tensile strength, the yield strength and hardness, but decrease the elongation at fracture after austenitizing at 950 °C. Only the furnace cooling has positive effect on elongation but all the other properties decreased. Thus, the furnace cooling is not an efficient way to improve in total. The air quench increases both the tensile and the yield strength, but when compared to austempering it is not a sufficient process. Water quench could be a solution for wear applications with it's high hardness but the goal of this study is to find optimum increasing treatment for all properties. The condition of austempering at 400°C and 30 mins is given best tensile and yield strength results. 400°C is relatively a high temperature for austempering that resulted low elongation property. Because at higher temperatures the diffusion rate of the carbon is also high. Thus carbon diffuses out from austenite structure and forms Fe_3C which reduces the elongation of matrix phase. But in general for S.S.F.D.I. material the high % Si content inhibits the formation of carbides, subsequently causing the carbon-enriched retained austensite and bainite.[10] For further studies, the lower austempering temperatures can be examined the get higher elongation with high tensile and yield properties.

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