New Approach to Assessing of High-Strength SG Cast Iron for Environmentally Clean Energy Technology

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Abstract

SG Cast Iron can be utilized advantageously as working materials in a number of devices which can contribute significantly to an environmentally clean energy technology. In this investigation microstructure and mechanical properties of ferritic-pearlitic spheroidal graphite (SG) cast iron is improve by continuous heat treatment and addition alloying of trace amount of tin has been study. Two standard Y-block was designed by in-mold process. Calculations and simulation were accomplished before molding by the Sutcast software. In each experiment, different chemical analysis were applied. The cooling curve of solidification was recorded by the datalogger with labview software and using S-thermocouple (Pt-Rh) attached into the mold. Then Y-block was shakeout from molds and cooled in the air standard specimen were machined for doing mechanical and metallographic exams. The metallographic exams has been indicated that with increasing the rate of shakeout time, the percentage of pearlite in microstructure has been increased. The mechanical test illustrated that with increase the rate of shakeout time, hardness and tensile strength have been increased, although the percentage of elongation and impact energy have been diminished.

Keywords: Spheroidal Graphite, High Strength, Continuous Heat Treatment, Clean Energy.

1. Introduction

The cast iron industry has developed rapidly and has played an important role in iron and steel research [1]. The microstructural characteristics, such as the amount of ferrite/pearlite, the nodularity rate, the nodular size and morphology, affect the mechanical properties of ductile iron significantly [2, 5]. High-strength SG cast iron using continuous heat treatment and tin trace element were study which can contribute significantly to an environmentally clean energy technology [6,7]. Among others, there are heat transformers and heat pumps which allow one to use low-quality thermal energy (e.g. waste heat) to generate high-quality thermal energy or cold, and there are thermal energy storage systems which can be applied in industry [8]. The mechanical properties of as-cast ductile iron is a functionally of microstructure. Part of this microstructure as shape, size and graphite formations is formed during solidification and the other part as microstructure around the graphite is formed during cooling rate [9]. Therefore change and produce pearlite microstructures around the graphite, it is suggested to use of an alloy element and heat treatment or both of them [10]. Many investigations have been indicated about the effect of alloy elements in as-cast or heat treatment in order to achieve pearlite microstructures [11]. Most of the reports regarding after casting heat treatment has been related to isothermal TTT (IT type) conditions , casts were cooled down in an appropriate rate in austenite temperature or were kept in a isothermal temperature for a given time in order to produced special microstructure [12]. using alloy elements and use them wisely [13].
Isothermal heat-treatment need special equipment [14]. On the other hand, the producers are limited in For this reason, the specimens can be cooled with higher cooling rate after shakeout from the molds [15]. It is possible to have conditions before eutectoid temperature in order to use trace alloy element because the cooling rate in the specimen is higher and there is no request to shift the cooling diagram with high alloy elements. So it is possible to have a special microstructure as pearlite [16].

2. Materials and Methods

Two Y-blocks standard (ASTM A536-89) shown in Fig. 1. and in-mould process in green sand used to production nodular graphite cast iron, Fe-Si-Mg 5% with 1 to 4 mm grain size was used in reaction chamber.

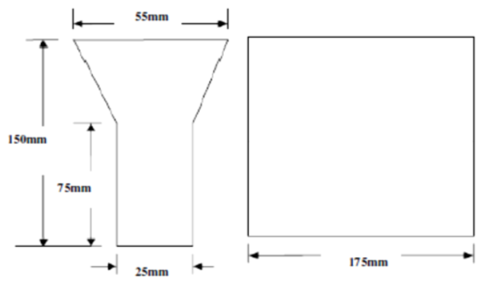

Fig. 1. Y- Block standard Dimensions ASTM A536-89.

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The simulation was done by Sutcast software and the graph were extracted and record the change of temperature in molds the S-type thermocouple (Pt-Rh) was attached to Datalogger with Labview (PCSDATA-810 and ADAM4000 software) shown in Fig. 2. Melt produced with steel scrap and Fe-Si 75% low frequency induction furnace.

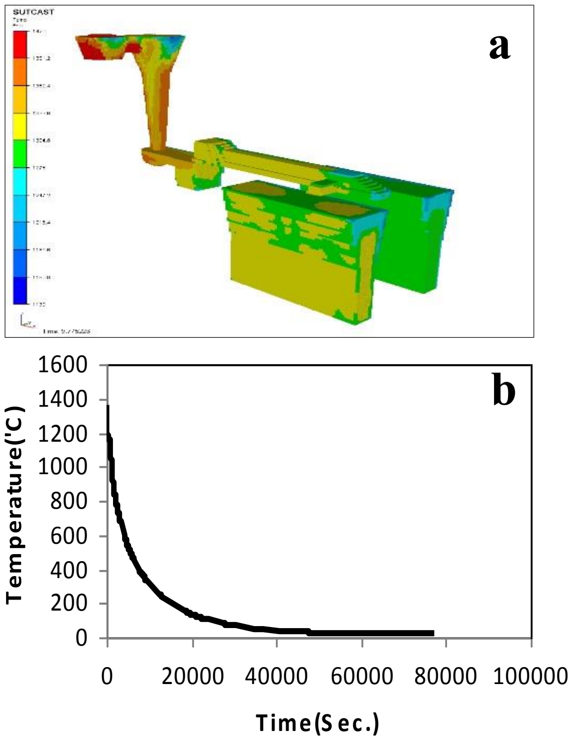

Fig. 2. (a) The simulation of specimen by Sutcast software (b) the graph were extracted by Datalogger with Labview (PCSDATA-810 and ADAM4000 software).

Melt was transferred in a pre-heated ladle and casting the melt in 1430 °c, then specimens were shakeout from the molds in higher than eutectoids temperatures. For this, 4, 6, and 8 minutes after casting, the specimens were shakeout from the molds, then cooled in the room temperature in the air.

Emission spectrometer was used for chemical composition analysis of Y-blocks.It should be noted that for determining of effect of trace elements 3 different heat casted. The optical metallographic carried out by Olympus microscope equipped to image analysis.

Then metallographic and mechanical specimens prepared. The tensile tests according to ASTM A536-89 and the impact energy tests according to ASTM A 327-72 were carried out. The Brinell hardness test used with 2mm indention and the weight of 187.5 kg.

3. Results and Discussion

Table. 1. indicate the chemical composition of specimens from molds and Table. 2., Table. 3., and Table. 4. indicate the results of metallography and mechanical exams.

Table. 2. illustrate results of mechanical exams and metallographic exams without Tin elements. As it can be seen, with increase percent of tin, the pearlite microstructure increased also this reason is effect of Tin in pearlite formation [17].

On the other hand, it can be seen from Table. 2., when the percent of tin element was constant, the pearlite in microstructure increased. This reason was cooling rate of the specimens out of the mold is higher than the austenite and eutectoid temperature [18].

Table. 1. The Chemical analysis of Y-blocks (Wt. %).

Heat No.	Chemical Composition						
	C	Si	S	P	Mn	Sn	Mg
1	3.210	2.520	0.022	0.041	0.430	–	0.045
2	3.220	2.520	0.021	0.038	0.420	0.003	0.045
3	3220	2.520	0.020	0.039	0.430	0.020	0.045

Table. 2. Result of mechanical test and metallography exam without Tin.

Heat No.	Sn٪	Shakeout Condition	No.	Microstructure		Hardness (HB)	Impact energy (J)	Tensile strength (MPa)	Elongation
				Pearlite ٪	Ferrite ٪				
1	0	Sample- cooled in mold	1 - 1	30	70	197	90	501	12
		4 minutes after casting	1 - 2	55	45	243	66	579	8
		6 minutes after casting	1 - 3	50	50	234	72	559	9
		8 minutes after casting	1 - 4	35	65	215	80	720	11

Table. 3. Result of mechanical test and metallography exam with 0.003% Tin.

Heat No.	Sn٪	Shakeout Condition	No.	Microstructure		Hardness (HB)	Impact Energy (J)	Tensile Strength (MPa)	Elongation
				Pearlite٪	Ferrite٪				
2	0.003	Sample - cooled in mold	2 - 1	35	65	217	84	520	11
		4 minutes after casting	2 - 2	75	25	267	48	637	6
		6 minutes after casting	2 - 3	65	35	254	53	608	7
		8 minutes after casting	2 - 4	55	45	245	66	579	8

Table. 4. Result of mechanical test and metallography exam with 0.02% Tin.

Heat No.	Sn٪	Shakeout condition	No.	Microstructure		Hardness (HB)	Impact Energy (J)	Tensile Strength (MPa)	Elongation
				Pearlite٪	Ferrite٪				
3	0.02	Sample - cooled in mold	3 - 1	40	60	224	79	540	10
		4 minutes after casting	3 - 2	95	5	287	30	765	4
		6 minutes after casting	3 - 3	85	15	274	39	716	5
		8 minutes after casting	3 - 4	75	25	268	47	674	6

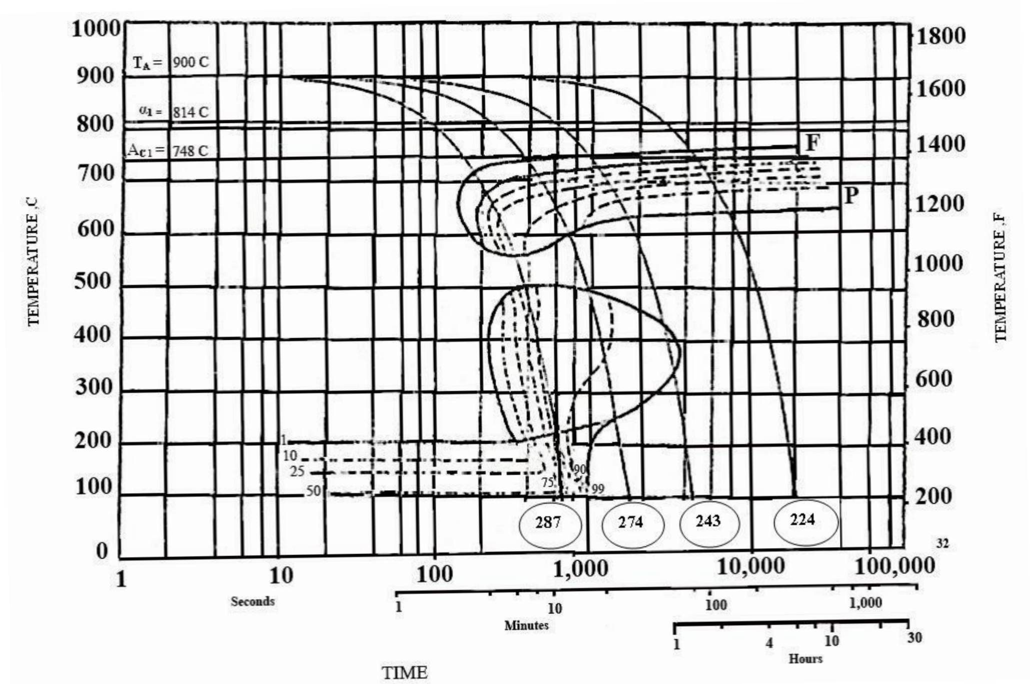

Fig. 3. Effect of shakeout on cooling rate at CCT diagram of ductile cast iron (Sample with 0.02% Tin).

Table. 3. and Table. 4. indicated that the shakeout time is constant, with increasing of the percent tin in chemical analysis of pearlite increases because tin is pearlite formation [19] and the effect of tin on situation diagram CCT of ductile cast iron [20]. In general, the investigations show that with increasing tin trace the hardness increases [21] and the CCT curve shifts to the right hand, so when the blocks are being cooled with increase of tin are in that blocks of the CCT curve that is for pearlite [22]. Fig. 3. indicates effect of the shakeout rate on diagram CCT of ductile cast iron (Sample with 0.02% Tin).

Results of the metallographic illustrated that it is possible to have the similar effect of tin trace element by increasing the shakeout rate of the blocks from the molds. For example, the sample with the No. 1-2 pearlite (the sample without tin alloy with the high shakeout rate 4 minutes after casting) is higher than the samples No. 2-1 and 3-1 (the samples with 0.003 and 0.02 percent tin alloy cooled in molds in room temperature, respectively). This shows that it is possible to do the cooling rate faster by increasing the shakeout rate from the molds in order for the cooling curve to have better position in CCT and also to have pearlite structure.

There will be no need to use alloy elements to shift the CCT curve and putting it in an appropriate position. Fig. 4. indicates the microstructure of two different blocks cooled in different condition.

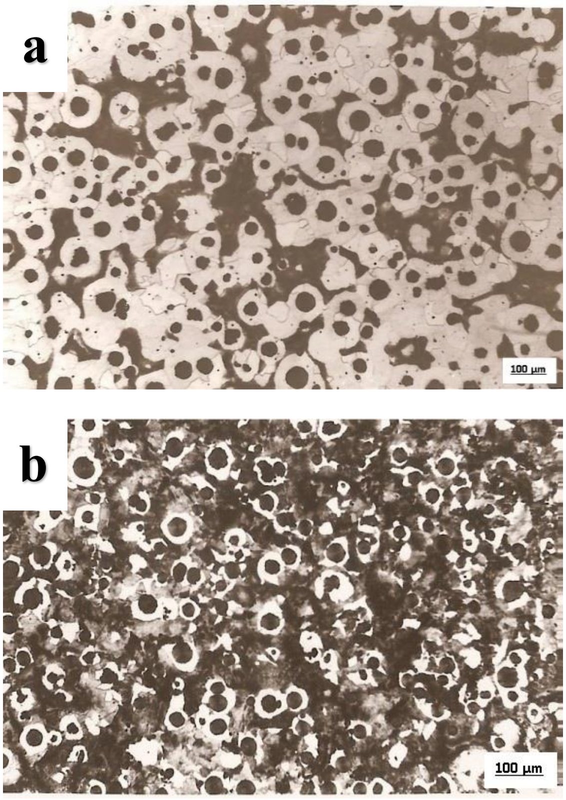

Fig. 4. Microstructure, a) Sample (Cooling in the mold until atmosphere temperature).
b) Sample with 0.02% Tin (Shakeout of the mold at 4min after casting).

Study of the Table. 3. and Table. 4. indicates that with increasing Tin trace in chemical analysis of Y-blocks increased tensile strength and hardness and decreases the elongation and impact energy.
Also with constant amount of tin the tensile strength and hardness increased and the elongation and impact energy decreased.
On the other hand, comparing the blocks with different amounts of tin shakeout at the same time shown that tensile strength and hardness of the specimens have higher percent of tin is more while the elongation and impact energy are less from the mechanical tests of the Table. 2. it is clear that it is possible to have been better mechanical properties in specimen without tin relative to specimen with Tin, by increasing the shakeout rate.
For example, the tensile strength and hardness of the sample with No. 1-2 (the one without tin and the shakeout time 4min after molding) is much higher than specimen No. 2-1 (sample having 0.003% Tin cooled to room temperature) and 3-1 (specimen having 0.02% tin) cooled to room temperature.
Fig. 5. to Fig. 8. show the effect of shakeout rate on mechanical properties according to the percent of tin (trace alloy tensile strength, relative percentage of elongation, hardness and impact energy).

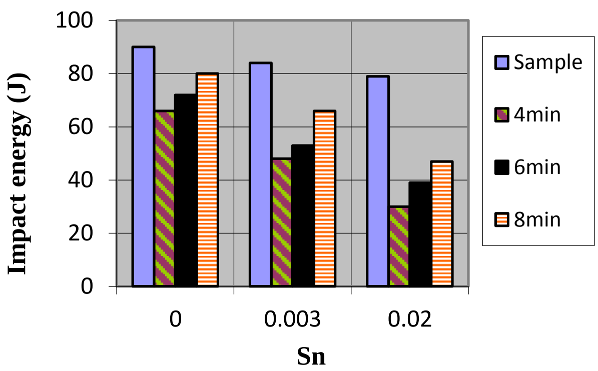

Fig. 5. Effect of shakeout time rate on the impact energy.

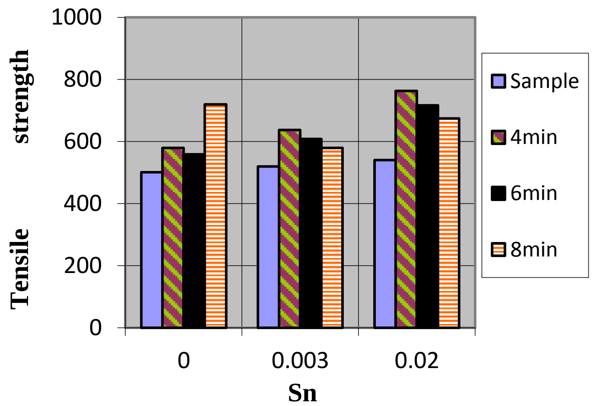

Fig. 6. Effect of shakeout time rate on the tensile strength.

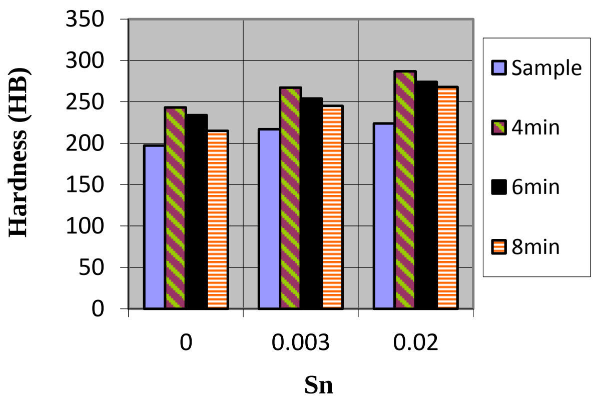

Fig. 7. Effect of shakeout time rate on the hardnes

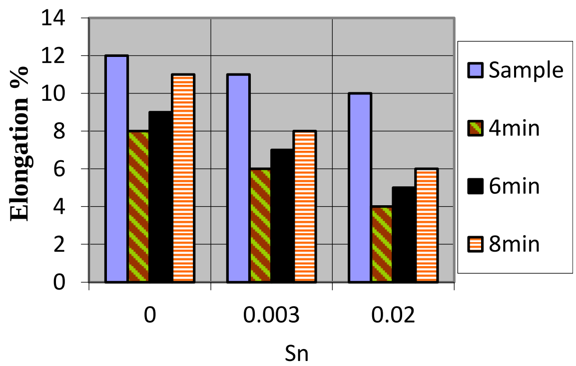

Fig. 8. Effect of shakeout time rate on the elongation.

4. Conclusion

In this investigation, new approach to assessing of high-strength SG cast iron using continuous heat treatment and tin trace element were study which can contribute significantly to an environmentally clean energy technology. Among others, there are heat transformers and heat pumps which allow one to use low-quality thermal energy (e.g. waste heat) to generate high-quality thermal energy or cold, and there are thermal energy storage systems which can be applied in industry. The most important result indicated that, it was possible to reach a certain percent of pearlite with only set up shaking out time and instead of adding pearlite formation element such as Tin, we could regulate shakeout time and the following results were obtained.

1. With Increased in tin trace alloy result in increasing of pearlite microstructure.
2. With Increased in tin trace alloy as well as shakeout rate after casting will result in increasing of pearlite microstructure.
3. With Increased in shakeout rate (without using tin) result in increasing of pearlite microstructure.
4. With Increased the pearlite result in increasing in tensile strength and hardness.
5. With Increased the pearlite microstructure result in decreasing in percentage of elongation and impact energy.

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