LOGIC
Journal of Engineering Design and Technology
Vol. 19 No. 1 March 2019 ; p. 25 - 33

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs.pnb.ac.id/index.php/LOGIC

TELLURIUM EFFECT ON ASTM A 220 GRAPHITE MALLEABLE CAST IRON

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Abstract. Malleable cast iron is an variant of cast iron which has rose-shaped graphite, the appearance of graphite due to the process of heat treatment. In general, a Boron element is needed in making the material. In this study, Tellurium was used as a substitute for boron. The main objective of the investigation was to determine the effect of tellurium composition on graphite microstructure and the mechanical properties of malleable cast iron. Variations in tellurium are added to the ladel, cast into specimen molds. Each specimen was subjected to annealing heat treatment at 900^0C and held for 10 hours. Then each specimen was tested in composition, microstructure, and hardness test. The test results showed that there was an effect obtained from the addition of tellurium to microstructure and hardness. Graphite structure increases from 2% to 6.5% and hardness increases from 38 HRc to 43 HRc.

Keywords: Malleable Cast Iron, Tellurium, Annealing.

1. INTRODUCTION

Malleable cast iron is cast iron which has middle class mechanical properties compared to ductile cast iron or other cast iron. This material provides good ductlity but has a higher toughness value than gray cast iron. Special application of this material is capable of being used in a bent or bent position but does not cause cracking. This material has good characteristics making it suitable for making pipe fittings, beam adapters, clamps, tools, connectors, and many more [2] [7].

The percentage of Malleable cast iron usage is equal to ductile cast iron. Especially for thin-wall castings, toughness exceeds ductile iron [6].

The hardness of ferritic malleable cast iron is expected to be around 110-156 HB, around 62–82 HRB (below 20 HRC) [8].

Figure 1 Some applications for using malleable cast iron

The process of making malleable cast iron goes through several stages, including alloy design, metal casting, and analing process. As for the metal casting process, the material is cast into white cast iron. Tellurium in malleable cast iron is usually added in the range 0,0005% to 0,001% to suppress mottle (graphite spots). Tellurium is a carbide stabilizer and has a stronger influence than bismuth during the freezing process. Tellurium was added to the ladel to ensure cast iron became a full white iron structure. But tellurium also has a strong influence on slowing down the annealing process in a content of more than 0.003%. Less than 0.003%, tellurium has a smaller influence on the annealing process, but it already has an influence on mottle control. Tellurium will be more effective if added with bismuth. In previous studies according to E.G Mekhanicheva: Tellurium was added when the liquid was in the ladle with a percentage of 0.01% - 0.6%. As a result, tellurium makes objects white and according to the study, the percentage of tellurium increases, giving rise to inclusion of graphite with increasing size, but the quantity decreases [7].

The purpose of this study was to determine the effect of Tellurium with a smaller content on Graphite Malleable Cast Iron ASTM A 220.

In this research, tellurium will be included in the print with a low composition of 0,0005% - 0,0025%. The hypothesis in this study is that tellurium will increase the size of graphite.

Malleable cast Iron is a type of cast iron that has a white structure, which has a very fine graphite element so that the distribution of Carbon elements is more evenly distributed and easily formed. Malleable cast Iron is divided into two types, namely: Whitehearth, Blackhearth, these names are terms in accordance with the microstructure of cast iron [3].

The process was originally made of white cast iron by applying a heat treatment. The heat treatment applied to white cast iron is generally annealed. By treating this Fe3C carbide phases will decompose to ferrite and graphite. Graphite formed is not shale or round, but in the form of clumps of graphite that do not have sharp edges.

The process of making malleable cast iron through two stages, namely metal casting and heat treatment. The first stage is the metal casting process. Iron in cast becomes white cast iron.

After finishing the metal casting process is complete, then the next step is the treatment process. The heat treatment or heat treatment process has three stages, namely heating, holding, and cooling. The heating process is the material heated at a certain temperature, then held until the homogeneous structure and finally cooled to a certain cooling rate to obtain the desired micro structure.

Heat treatment of cast iron can determine the final structure of this iron. There are two basic stages for forming this iron. In the first stage, iron carbide is broken down into austenite and graphite. In the second stage, austenite is converted to pearlite, ferrite, or both alloys. Even though there is a difference in composition between ferritic and perlitic castings, the difference mainly in the heat treatment cycle. To form a ferritic structure is needed to decrease the temperature in the range of 3 to 10 ºC / hour through eutectoid transformation in the second stage. This is needed to make a complete change from austenite to ferrite. When ferritic forging is made, the scheme used is different, the main goal is to achieve eutecoid transformation to convert austenite to pearlite.

In the manufacture of Ferrtitic-Malleable Castron there are 2 stages of Graphite formation; First-Stage Graphitization & Second-Stage Graphitization. For the manufacture of Pearlitic-Malleable Cast Iron, the heat treatment is given in stage one then the cooling is given air cooling without the second stage.

First-Stage Graphitization. It was heated to temperatures of 850-900 ° C for ± 6 hours, held at a temperature of 900-970 ° C for 10 hours and decreased the temperature to 740 ° C quickly. The first stage of the nucleation formation of carbon tempering begins during heating towards the holding temperature and occurs very early during the holding time. During the containment phase, the existing carbide decreases from the iron structure, the splitting of the cerbide will begin to move. The length of holding time gives Graphite an opportunity to gather to other Graphites. When carbide is reduced, iron is rapidly cooled to 740 ° C first, to enter the second stage of Graphite formation.

On Stage Graphitization. slow cooling through extensive allotropic transformation of iron. During this process, simultaneously the free matrix Ferrite from pearlite and carbide is formed with a cooling speed of 2 to 28 ° C / h (3 to 50 ° F / h). This stage can not be carried out to form a perlitic microstructure [4] [5].

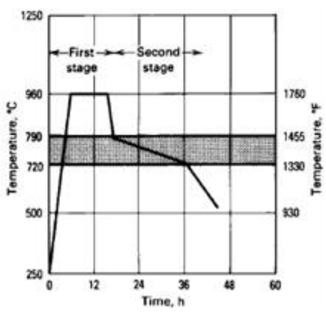


Figure 2 Diagram of annealing in forged cast iron [4]

2. METHODS

The research was carried out by the method as illustrated in the following flow chart:

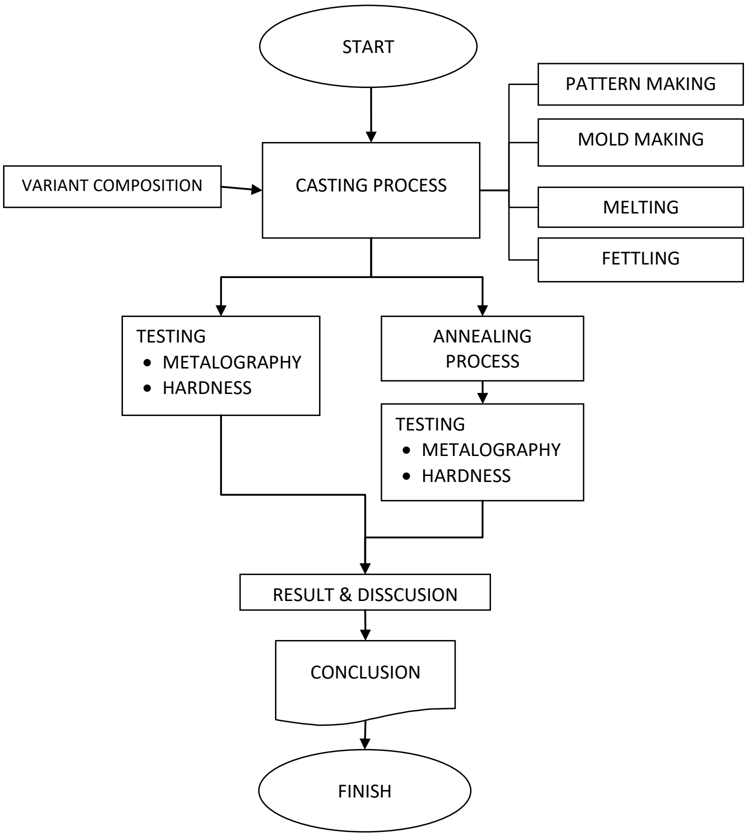
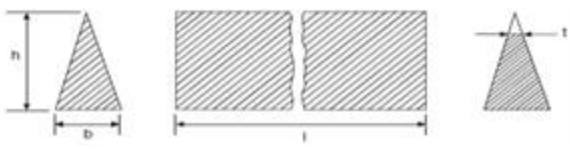


Figure 3: Flowchart of the Research Methods

The research activity was carried out by experimenting with making cast objects with triangular rods according to standards. Starting from designing variations of tellurium alloys, and designing and making patterns that will be used. Malleable cast iron materials are commonly used as pipes, or joints. The thickness of the pipe used is usually 12.5 mm, so the size of the test sample is in the form of a triangle with a base of 13 mm. The following is the size of the test sample shown in the image below.



Base (b)		Height (h)		Length (l)	
mm	in	mm	in	mm	in
6	1/4	11	7/16	57	2 1/4
13	1/2	22	7/8	100	4
19	3/4	38	1 1/2	127	5
25	1	57	2 1/4	127	5

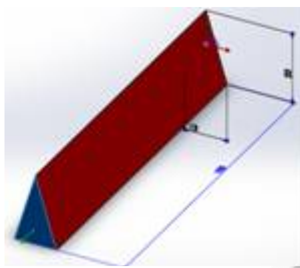


Figure 4 Test sample size (a) and Design of the test sample (b)

The size of the test sample was chosen from the size of the thickness. The test sample had the size of 13mm x 22mm x 100mm = 14300mm³ = 0.00143 dm³, using a specific gravity of 7.45, then weighing = 106.5grams.

The variable percentage of tellurium alloy is taken from the percentage of tellurium used in the CE meter. From the results of testing the composition, the value of 0.00144% is rounded up to 0.0015%. This value will be used as a reference for the tellurium variable used. The following is a draft calculation of tellurium.

Table 1 Calculation of tellurium alloys

Nr.	Sample	Tellurium percentage	Tellurium Weight
1	Sample 1	0,0005%	0,0018 gram
2	Sample 2	0,001%	0,0036 gram
3	Sample 3	0,0015%	0,0054 gram
4	Sample 4	0,002%	0,0072 gram
5	Sample 5	0,0025%	0,0091 gram

After the test sample has been prepared, the next is the metal casting process. The metal is cast at a temperature of 1458°C, with the alloy target composition as follows:

Table 2 Composition of ASTM A 220 [1]

Component Elements Properties	Metric
Carbon, C	2.0 - 2.9 %
Iron, Fe	95 %
Manganese, Mn	0.25 – 1.25 %
Phosporus, P	<= 0.05 %
Silicon, Si	1.0 – 1.75 %
Sulfur, S	0.030 –0.18 %

Figure 5 Casting process of samples in a mold (Tellurium powder is inserted into the mold before being cast)

The sample is prepared with an existing code, aligned with the test mat. 5 samples were inserted into the HT furnace. Increased from room temperature to 900 ºC within ± 6 hours, detained within 10 hours. The following is a graph of heat treatment performed [4].

Figure 6 Time-Temperatur curve of Annealing

At this stage, second-stage graphitization is not carried out to form the pearlite structure. The following is a picture of the stages of the heat treatment process carried out:

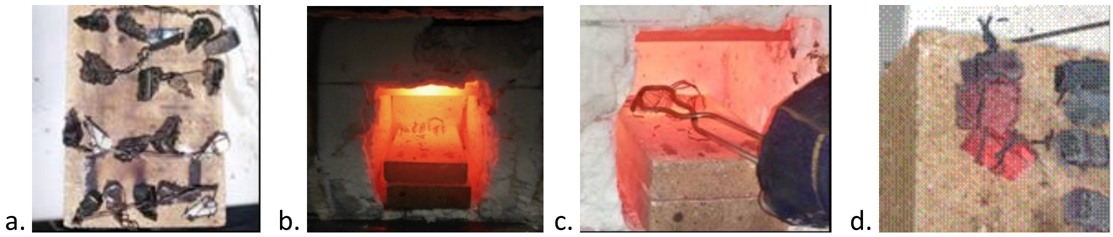


Figure 7 Preparation of test samples (a. Binding, b. Heating in the furnace, c. pulling out, d. cooling)

3. RESULTS AND DISCUSSION

Composition testing was carried out using the ORL brand ARL Spectrometry machine. From the composition testing performed, the following results are obtained:

Table 1. Reseacrh Subjects Characteristic Summary

Composition	Standard	Test Result
Carbon	2.00 – 2.90 %	2.80 %
Mangan	0.25 – 1.25 %	0.80 %
Silicon	1.00 – 1.75 %	1.34 %
Sulfur	0.03 – 0.18 %	0.03 %
Phospor	<= 0.05 %	0.02 %

In addition to composition testing using a spectrometry machine, samples were also tested for compositions using the EDS machine to detect tellurium. The following are the results of the SEM-EDS test:

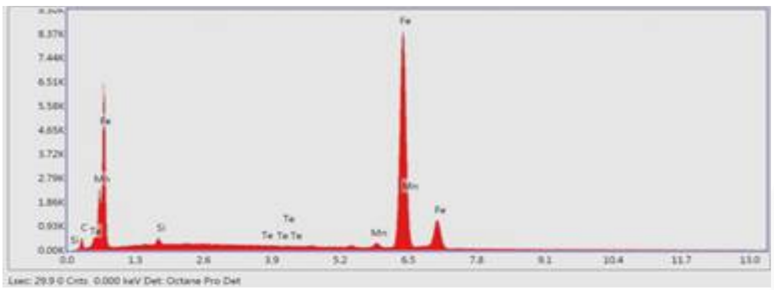
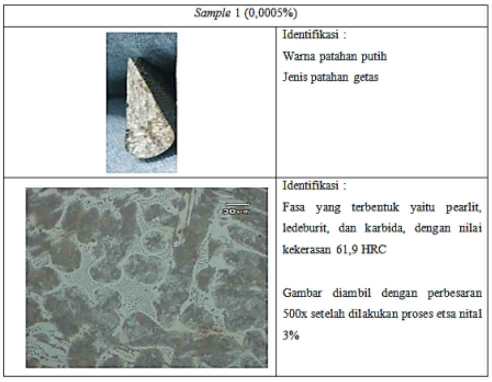
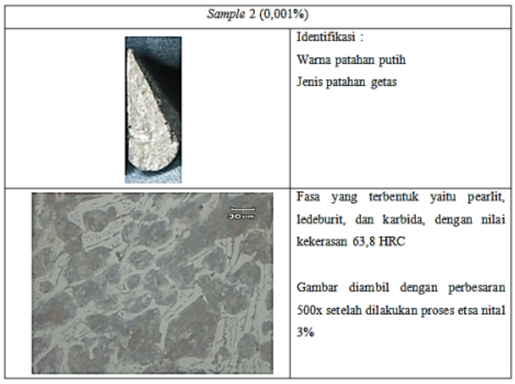
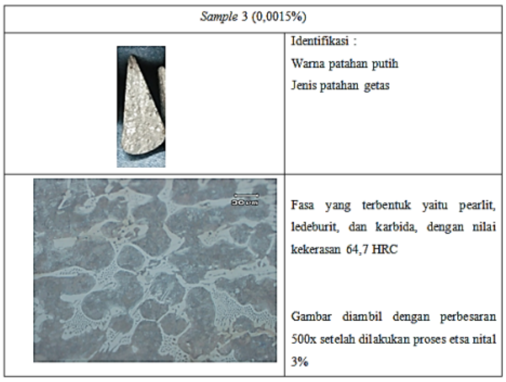


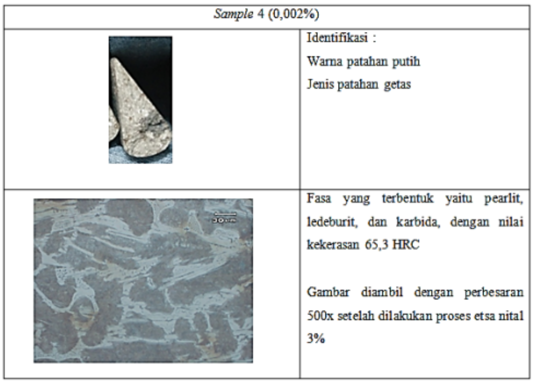
Figure 8 EDS test results

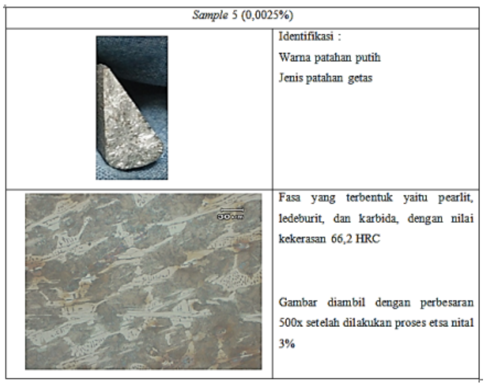
After the casting process, the analysis process is carried out from the test results. The following are the test results from each sample:

a.


b.


c.


d.


e.


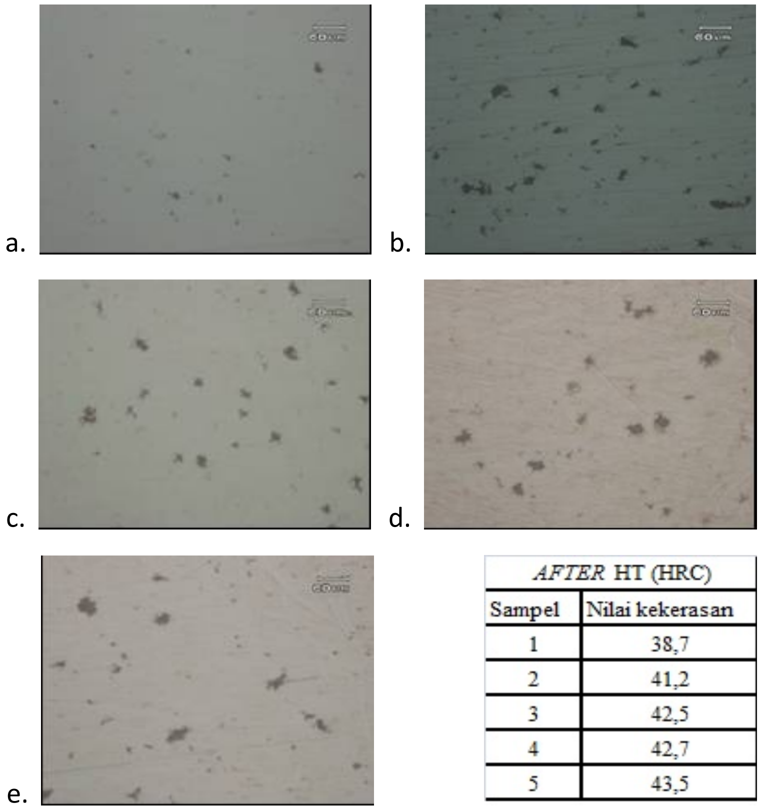
BEFORE HT (HRC)	
Sampel	Nilai kekerasan
1	61,9
2	63,8
3	64,7
4	65,3
5	66,2

Figure 9 Test results of samples as cast: cross section break surface and microstructure with 3% Nital etching: pearlite, ledeburit, and carbide:
a. sample no.1 (0,0005 Te), b. sample no.2 (0.001 Te), c. sample no.3 (0.0015 Te), d. sample no.4 (0.002 Te), e. sample no.5 (0.0025 Te)

After the heat treatment process, metallographic testing is carried out. In this process, graphite is taken from each sample. As for the testing position, it is in the middle of the sample. Next is the test area of each sample:

Figure 10 Metallographic testing area on the sample

The following is a non etching image from the Heat Treatment process. Images are taken with 200x magnification after the polishing process is done using alumina:



AFTER HT (HRC)	
Sampel	Nilai kekerasan
1	38,7
2	41,2
3	42,5
4	42,7
5	43,5

Figure 11 Samples 1 to 5 after heat treatment non etching 200x magnified:
a. Sample Nr. 1 (38.7 HRc.), b. Sample Nr. 2 (41 HRc.), c. Sample Nr. 2 (42.5 HRc.),
d. Sample Nr. 2 (42.7 HRc.), e. Sample Nr. 2 (43.5 HRc.)

From the test results, the analysis is obtained as follows:

1. All samples have the same microstructure phase, namely, ledeburit, pearlite, and cementite. And all samples have white faults. This means that before entering the treatment process, tellurium does not appear to affect the as cast material (seen from the phase type) at this stage.
2. Value of the phase hardness, there is an increase along with the addition of tellurium. The hardness testing area can be seen in the following picture:

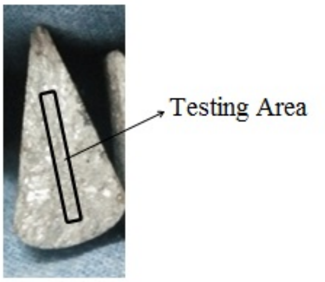


Figure 12 Hardness Testing Area

3. After doing heat treatment, there is no difference in the results of the non-etching image, with a magnification of 500x. For more details, can be seen in the table below.

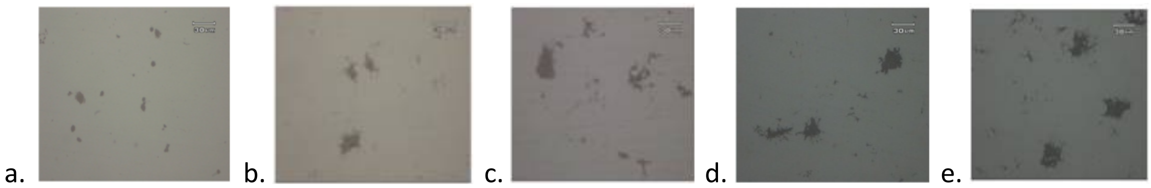


Figure 13 form of graphite sample 1 to 5 after annealling (graphite percentage):
a. Sample Nr. 1 (2%), b. Sample Nr. 2 (2.43%), c. Sample Nr. 3 (3.5%),
d. Sample Nr. 4 (3.6%), e. Sample Nr. 5 (6.5%)

4. Because the form of graphite does not look different, graphically the percentage of graphite is calculated. The results are as follows:

Table 4 Percentage value of graphite

Nr. Sample	Graphite Percentage
Sample 1	2 %
Sample 2	2.43 %
Sample 3	3.5 %
Sample 4	3.6 %
Sample 5	6.5 %

5. After the heat treatment process is carried out, the results show that tellurium has an influence on the size of graphite.

4. CONCLUSION

The results showed that all samples had white fault color or white cast iron with a structure before the heat treatment, ledeburit. After the heat treatment process is carried out, the results show that tellurium has an influence on the percentage of graphite in each sample. From the research that has been done, with the addition of tellurium the percentage of graphite becomes increased, from 2% to 6.5%. In addition, with the addition of tellurium, the value of material hardness has increased along with the percentage of tellurium added with a range of 38.7 HRC - 43.5 HRC.

From the research that has been done it can be concluded that tellurium has an influence on the form of graphite in malleable cast iron material.

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