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The Effect Cryogenic Cooling, Martemper And Temper Of Micro Structure And Hardness Ductile Cast Iron (FCD-45)

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Abstract

The purpose of this study was to test the Cryogenic Cooling Effect Mar temper and Temper of the hardness and microstructure of Ductile Cast Iron (FCD-45). Heat treatment process the test material with the heating process starts from 0^{o}C to 600^{o}C. Heating interval is done so that the specimen does not have cracks, holding for 45 minutes. Furthermore, heated again to 900^{o}C (temperature austenite), and hold 60 minutes. Then the process is continued, the specimen was cooled to put another Furnace heating at a temperature of 200^{o}C for 10 minutes. Subsequently the specimens removed from the Furnace in a state of 450^{o}c temperature and put in the water until it reaches room temperature. Specimens reprocessed by entering into liquid nitrogen with -193^{o}C temperature for 120 minutes. Test objects are removed from the liquid nitrogen, heated in an open space until it reaches room temperature, 30^o-35^{o}C. Final heat treatment process of the test object is, put in the Furnace heating (tempering process) at a temperature of 200^{o}C for 60 minutes.
FCD-45 (As-Cast) after being subjected to mar tempering, and tempering of ductile iron (*Matdi*), the hardness increased from 86 to 90 HRB. But if FCD-45 (As-Cast) subjected mar temper, cryogenic, and temper of ductile iron (*Mactdi*) process will result in increased hardness of 86 to 94 HRB. FCD-45 (As-Cast) having microstructures of perlite, ferrite and graphite nodules. *Matdi* process produces microstructures of perlite, ferrite, graphite nodules,

residual austenite and martensite tempered. As for the process *Mactdi* produce microstructures perlite, ferrite, graphite nodules and martensite. The amount of martensite generated in the process Mactdi more when compared with the amount of martensite produced in Matdi process.

Keyword: Hardness, FCD-45, Matdi, Mactdi

INTRODUCTION

Nodular Cast Iron originally found in the UK, from the casting process with the addition of cerium element in addition to other elements by the British Research Association in 1948. The cast iron is known also in Japan and America with the name Ductile Cast Iron (ductile cast iron), in Indonesia known the name *bergrafit* round cast iron. Nodular means round. This cast iron microstructure consists of perlite, ferrite and graphite. Graphite in cast iron is spherical. Graphite is a round or nodules, has a degree of stress concentration is very small, then the strength of cast iron for the better. In its development, this kind of cast iron cast iron also called clay (Tata Surdia, 1992). Cast iron is in addition known as Cast Ductile iron, also known as spheroidal Graphite Iron (SG Iron) or spherilitic Iron. Because of its superiority compared with other cast irons, which have good ductility, corrosion resistance and heat resistance, therefore, cast iron is used for various purposes, for pipes, mold grinding rollers, components for furnaces and for civil engineering construction (Tata Surdia, 1992)

Mar temper and Temper Ductile Iron (Matdi), is one of the methods on the scope Heat treatment to improve the mechanical properties of Ductile Cast Iron (FCD-45), Matdi method is very strong following in the footsteps on TTT- process diagram (Time Temperature, Transformation) and CCT diagram (Continuous Cooling Transformation). The development of the method is a method Matdi MACTDI (Mar temper, Cryogenic and Temper Ductile Iron), in which the method is there one additional treatment, with cooling (immersion) specimen into liquid nitrogen.

Against Ductile Cast Iron Never do research. Class FCD studied were FCD-60. The purpose of this study to improve the mechanical properties of the cast iron. The mechanical properties were investigated and are expected to increase, are: hardness, impact and tensile strength. Mechanism research with the addition of several elements such as Ni: 1%, Mo: 0. 15%, Ce: 10. 2% and the ADI (austempering Ductile Iron). The materials tested were FCD-60. The results of the study show a significant increase of the mechanical properties of the FCD-60, namely the tensile strength increased from 59. 15 kg / mm^2 be 133. 66 kg / mm^2. Impact increased from 5. 48 Joule / cm^2 be 11 Joule / cm^2, and a change in the microstructure into bainite, (Sudarsono, 1977)

Research on Nodular Cast Iron in order to determine changes in tensile strength and toughness with methods one and two-step austempering heat treatment. The results of a two-step austempering heat treatment is, tensile strength and toughness, showed increased values compared with the results of one step austempering. The process of taking one step method, performed by heating at a temperature of 900^{o}C with holding austempering 60 minutes. Then cooled in a saline solution at temperature 280^{o}C, 310^{o}C and 340^{o}C and hold for 60 minutes and 120 minutes respectively.

In the two-step austempering process, the process is done by heating at a temperature of 900^{o}C, holding 60 minutes. All specimens were cooled at a temperature of 260^{o}C for 10 minutes. The next process is reheated specimens each at a different temperature is 280^{o}C, 310^{o}C and 340^{o}C in-holding each 60 minutes and 120 minutes. The highest results for the mechanical properties (toughness), heating at a temperature of 280^{o}C, while the highest tensile strength obtained at 340^{o}C temperature heating by respective holding 60 minutes. (Andoko, 2013)

SK Shaha (2010), in this study Ductile Cast Iron advance combined with Fe-C-Al. Then processed Heat Treatment with ADI method (Austempering Ductile Iron). Run method is to impose a fine on the time variation of austempering temperatures (800-900), and the variation of the holding time. Holding time after austempering process at 350^{o}C temperature varies from 1until 4 hours. The results of this study are Impact strength increased from 67. 93 Joules / cm to 104. 5 Joules / cm. Because of the tempering process, then a change in hardness of 100 HRB, to 78 HRB. Austenitic structure formed rising and Ausferrite be rough with increasing time. Austenite percentage increased from 26% to 43%.

Cryogenic Treatment is the treatment of cooling a material either metal or nonmetal. To be steel and can also cast iron (cast iron). The movement began temperature room temperature to a temperature -360^{0}F (-196^{0}C), then at the temperature of the test specimen at-holding (silenced) at that temperature until a certain time, then the specimen removed from immersion and placed in an open space until it reaches room temperature (Agus Suprapto, et al, 2014). Cooling material is divided into two, the first is called with Subzero cooling is done at temperatures -145^{o}C (-230^{o}F), which both Sryogenic Treatment; carried out at temperatures -195^{o}C cooling using liquid nitrogen, Singh, S, et al, (2012), Ramji BR et al, (2010), Rajendra K. et al, (2007).

Research at Cryogenic treatment and tempering method performed on carbide tool in turning the AL-6061. The method is a carbide tool (As-Cast) modification, immersed into liquid nitrogen at -195^{o}C, with a holding time of 2 hours, 24 hours, and 48 hours; each of 6 (six) specimen. Testing the second is equal to the first test, where after a testing mechanism mentioned above, further in-tempered specimen at a temperature of 150^{o}C, hold for 1 hour. After treatment, the initial specimen (as-cast) and the test object modification, each formed into test specimens with a chisel shape pieces of iron carbide material. Further testing conducted by the process turning the spindle rotation speed predetermined cutting depth and variation of the AL-6061. The purpose of this study is to determine how much wear that occurs in both the As-Cast cutting chisel and chisel cut modification. The results of this study are: (1) The results in slaughtering, cutting chisel edge wear bigger. (2) The results of cutting chisel (carbide tool) from the cryogenic treatment, the better the resistance to wear and tear. Similarly, carbide tool cryogenic + tempering treatment results are also better results when compared with the wear resistance of carbide tool As-Cast. (3) Microstructure for carbide tool modification either by cryogenic treatment and cryogenic treatment +

tempering, there is accumulation of granules AL-6061 is thinner than the As-Cast carbide tool (Agus Suprapto, et al 2014).

Differences that occur between previous studies with this research is; previous research has much to do research with ADI method (Austempering Ductile Iron) with slight modifications as additional process. For this study in addition there is a portion of the ADI is used, then the process of being built in this research is a new method, namely MATDI (Mar temper and Temper Ductile Iron) and Methods MACTDI (Mar temper, Cryogenic and Temper Ductile Iron). The second method provides improved the mechanical properties of the metal.

MATERIAL AND METHODS

Before performing heat treatment and cooling as well as testing, raw materials Ductile Cast Iron (FCD-45), produced by from the foundry with dimensions of 22 mm diameter and length of 80 cm. Of the number of as-cast that has been prepared for the research, partly formed for tensile test specimens, in order to determine and ensure that the raw material is really FCD-45. Having in mind that the as-cast is FCD-45, then the next process raw materials-the raw material is cut into pieces with a length of 32 cm and then in-heat treatment with Matdi and Mactdi method as shown in diagram 1 and 2. As-Cast tested composition (chemical test) with standard test ASTM E 415-08, ASTM E 350-95 with following results: Carbon: 5. 9%, silicon: 2. 9%, phosphorus: 0. 00413%, Fe: 81. 84 %, Zn: 0. 01866%, Mn: o, 121%.

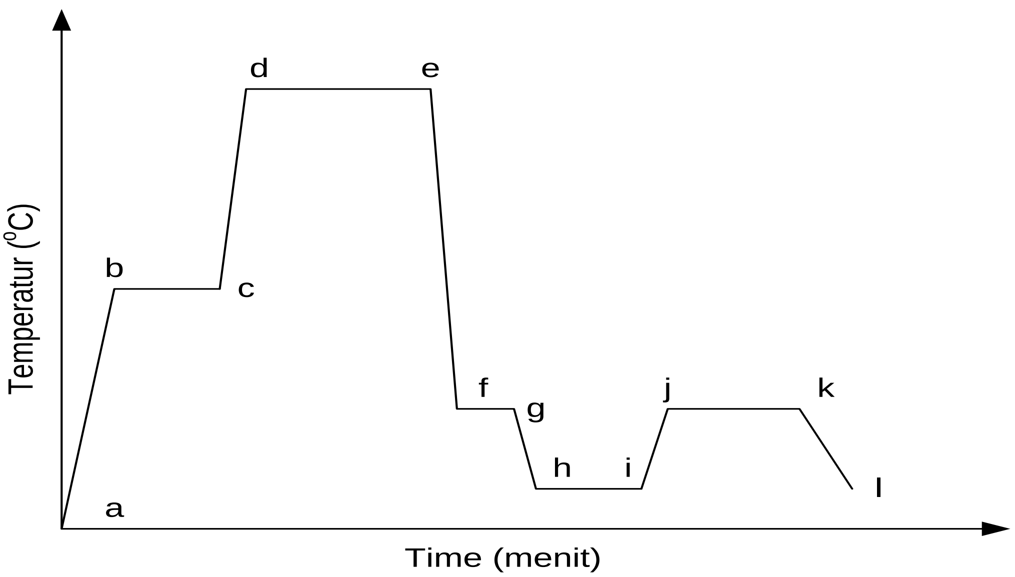


Figure 1. Diagram Heating and Cooling Vs Time In Process MATDI

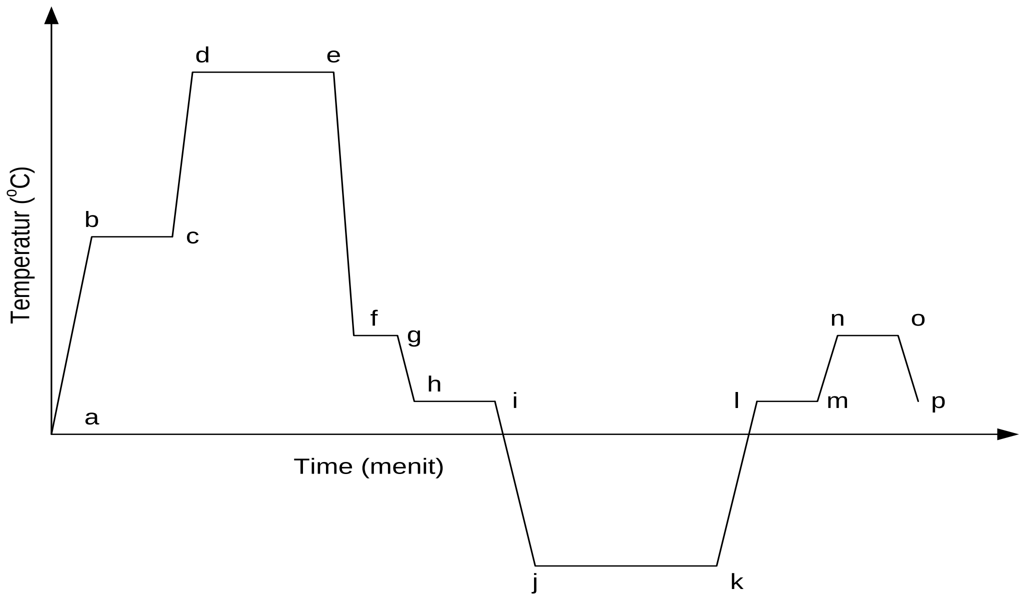


Figure 2. Diagram of Heat Treatment and Cooling VS Time In Process MACTDI

Figure 1 and 2, the line ab is heating the as-cast from 0^oC - 600^oC. Heating to 600^oC is as preheating (preheating) with the goal of the test object does not have cracks when it will be raised temperature be 900^oC (austenitation). At temperatures of 600^oC as-cast hold 45 minutes (b-c). Furthermore, the specimen heated to 900^oC (c-d). And on this temperature specimen hold 60 minutes (d-e). In this heat treatment process used two heaters furnace. The next process the specimen removed from the furnace and immediately inserted into the furnace 2 where the temperature is 200^oC for 10 minutes (e-f-g). Test specimens were removed from the furnace 2 still contains heat until 450^oC, then put into the water until it reaches room temperature, (h-i). The final step in the process is the specimen Matdi in-tempered at a temperature of 200^oC and in-holding for 1 hour (J-K), the specimen was cooled in an open space until it reaches room temperature, (l).

In figure 2 after passing cooling process with water (h-i), until it reaches room temperature, the specimen subsequently dipped into tubes containing liquid nitrogen with temperature -193^oC for 120 minutes (J-K). Test objects are removed from the liquid nitrogen tube, heated at temperature space (L-M). Once the specimen reaches temperature space, then tempered at a temperature of 200^oC for 60 minutes (N-O), the last step of the test specimen was cooled in air space, (P).

After the heat treatment and cooling process is complete, the test object is formed for hardness testing, micro structure, SEM and other tests. Used to test hardness testing machine Rockwell Hardness Tester (HR - 210 MR Mitutoyo), all specimens of As-Cast to modify the test object is formed in accordance with the testing to be performed. Tensile test used ASTM (A379 - 2002). Impact test used

ASTM A327 using charphy Impact Test. All specimens were tested, starting from testing of As-Cast, then testing of the specimen Mactdi and Matdi treatment.

RESULTS AND DISCUSSION

Table 1 hardness test specimens used were four samples each for each treatment. Hardness results obtained for As-Cast occur linear increase in hardness of the samples 1-4. Results hardness for treatment Matdi is a linear increase in hardness of the samples 1-4. Similarly, the results obtained from the treatment of hardness Mactdi is a linear increase in the hardness of the samples 1-4.

Figure 3, the histogram seen the end result of mechanical properties average hardness of each treatment. As-cast after receiving treatment Matdi, an increase in hardness as seen in Figure 3. Similarly, the As-Cast after receiving treatment Mactdi, hardness change, in which the hardness increases, beyond hardness with Matdi treatment.

Table 1. The average hardness values at various conditions

Spesimen	I						II						III						IV						R2
Perlakuan	1	2	3	4	5	R1	1	2	3	4	5	R1	1	2	3	4	5	R1	1	2	3	4	5	R1	
As-Cast	84	84,5	84,3	84,1	84,1	84,2	86,5	87	86,5	86,7	86,7	86,68	86,5	87	86,7	87,5	87,5	87,04	87,5	85,5	86,5	88	88	87,1	86
Matdi	87	88,1	90,6	89,4	90,8	89,36	88,6	89,1	88	90,3	91	89,4	89,6	90,3	90,4	90,7	90,9	90,36	90,3	91,3	90,60	90,60	90,5	90,66	90
Mactdi	90	90	91,5	94,9	91,4	91,56	94,2	95,6	90	90	91,5	92,26	90,6	97,9	91	96	94,4	93,98	94,5	100,5	95,5	99,2	101	98,14	94

Description

R1 = Hardness average each specimen
R2 = average of all specimens at various treatment
As – Cast = Specimen Standard
Matdi = Mar temper and Temper Ductile Iron
Mactdi = Mar temper, Cryogenic and Temper Ductile Iron

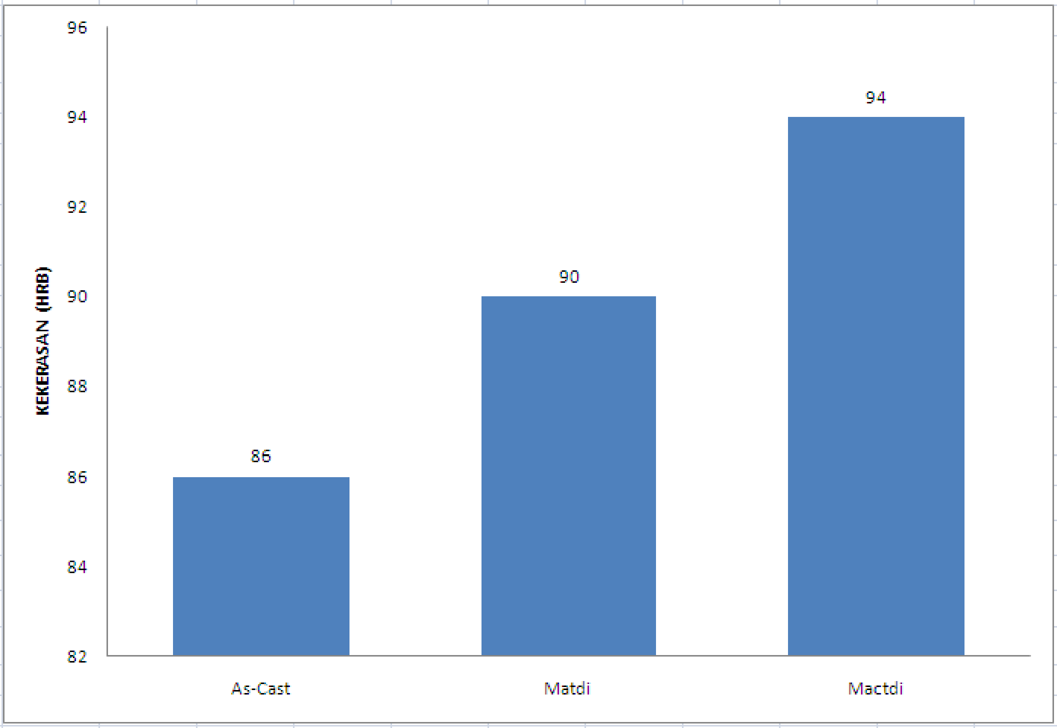
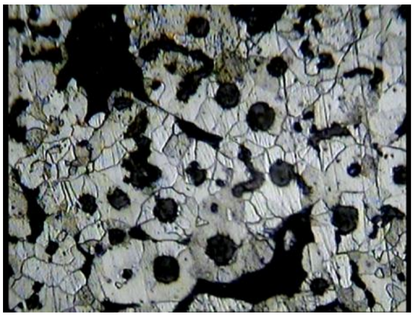
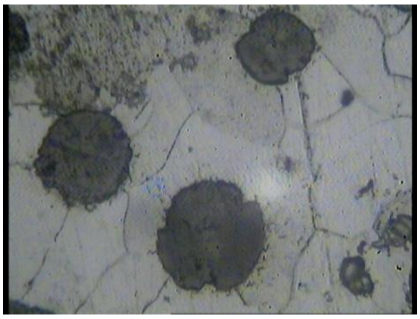


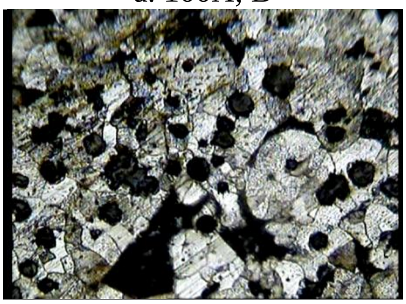
Figure 3. Graph the average hardness values at various conditions



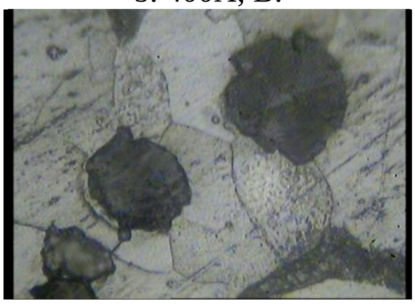
a. 100X, B



b. 400X, B.

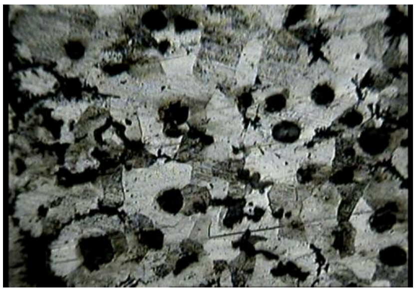


a. 100X, A

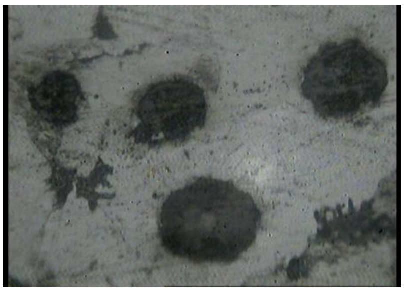


b. 400X, A.

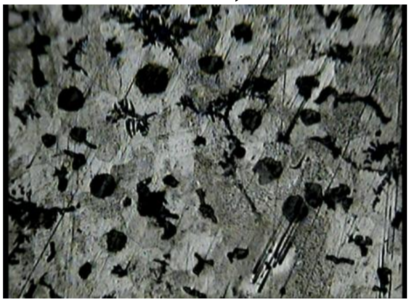
Figure 4. Structure of Micro As – Cast



a. 100X, D



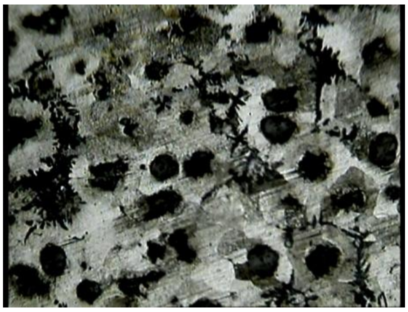
b. 400X, D.



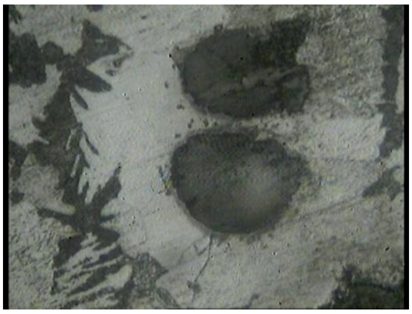
a. 100X, A

b. 400X, A.

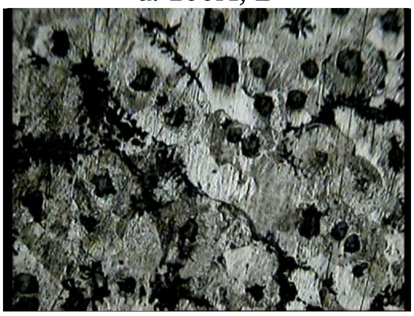
Figure 5. Structure of Micro Mar temper and Temper



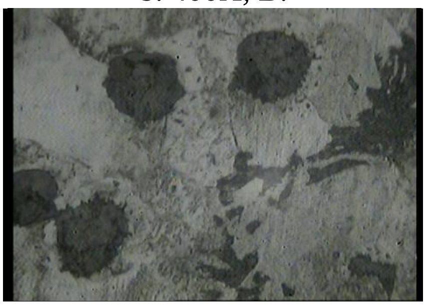
a. 100X, B



b. 400X, B.



a. 100X, C



b. 400X, C

Figure 6. Structure of Micro Mar temper, Cryogenic and Temper

Discussion

In figure 3 the histogram shows the final result of the treatment of the test object FCD-45 in which the specimen after being subjected to an increase in hardness matdi. Increased hardness occurs after FCD-45 have austenite process and holding for one hour. Austenitic microstructure after experiencing mar temper process and cooling water, there will be a transformation in which austenite will transform into martensite. In the cooling process of 900^{o}C to 200^{o}C temperature in the furnace to 2 for 10 minutes. The process of change is already underway in which the FCC crystals will turn into crystals BCT with martensite microstructure. When the specimens were removed from the furnace, the specimen temperature was still in the position 450^{o}C. In the specimen temperature, then put in the water, then rapid cooling occurs, the lower the cooling temperature, the more transform austenite to martensite. Because martensite has mechanical properties of high hardness but brittle, then do tempered with a time of 1 hour, the temperature 200^{o}C. For 1 hour tempering process is done so that the softening occurs in the test specimen. In the picture no. 4, looks microstructure FCD-45 before modified. Microstructure is composed of perlite, ferrite and graphite nodules, which distinguish the FCD with cast-iron iron castings such as white cast iron, gray cast iron, malleable cast iron and compact cast iron each in the form of graphite. For FCD average graphite spherical, rounded shape is due influenced elements contained in it such as Si (Avner, 1987), in which the shape of the spherical graphite as the cause of the FCD is superior to cast iron cast-iron the other.

In Figure 3. The graph histogram shows an increase in hardness in the mactdi (mar temper, cryogenic and tempered ductile iron). The increase in hardness is caused by the cooling with liquid nitrogen under 0^{o}C (-193^{o}C) for 2 h, the cooling process from 35^{o}C to -193^{o}C will happen transformation from austenite to martensite rest where the addition of martensite microstructure as seen in Figure microstructure cooling cryogenic. (Figure 6).

In figure 5; is the microstructure of treatment Matdi, where visible presence of ferrite, perlite, graphite nodules and martensite. Martensite microstructure is strongly suspected cause of increased hardness FCD-45 after receiving treatment Matdi. In this Matdi process, ie the process is already occurring changes mar temper microstructure of austenite to martensite. These changes continue at the time the specimen is dipped into the water, then there is increase in the martensite microstructure of the specimen. Because of this specimen is more desirable soft (ductile), then do tempering which causes the martensite microstructure will be reduced, as seen in Figure 5.

In figure 6; is the microstructure of treatment Mactdi, where some of microstructure is ferrite, perlite, graphite and martensite. The amount of martensite in the FCD-45 modification is much more when compared with the amount of martensite in the FCD-45 in the treatment Matdi. The increase is due to the amount of martensite of treatment specimens cooled down with liquid nitrogen at temperature -193ºC. Residual austenite by rapid cooling will increase the amount of residual austenite transforms to martensite. Because it appears in Figure 6, the martensite more numerous than that of the martensite microstructure on Matdi treatment. Allegedly with the addition of the amount of martensite microstructure Mactdi process, the higher hardness properties when compared with the microstructure on Matdi process. It appeared then in figure 3, the histogram graph shows a linear increase in hardness of As-Cast, Matdi processes and Mactdi process.

CONCLUSION

1. Value of hardness increased for FCD-45 (As-Cast) after processing Matdi (Mar temper and Temper Ductile Iron).
2. Value hardness FCD-45 (As-Cast), increased height in the process Mactdi (Mar temper Cryogenic and Temper Ductile Iron) exceeded the value of hardness FCD-45 (As-Cast) Matdi process.
3. In the microstructure FCD-45 (As-Cast), microstructure consisting of graphite nodules, Perlite and Ferrite.
4. In the treatment Mactdi and Matdi microstructure to martensite, ferrite, perlite and graphite nodules.

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