Influence Of The Triple Spheroidization On Surface Hardness From Drilling Resistance Behavior Of Powder Coated Gray Cast Iron

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Abstract: The objective of this study on the influence of the triple spheroidization on surface hardness from drilling resistance (Dry drilling) of powder coated gray cast iron using universal testing machine (Compressive mode), the surface hardness in powder coating areas, normal hardness and Charpy impact resistance were considered. The spheroidizing temperatures were 300°C, 450°C and 600°C; the spheroidizing time spanned the range of 6 hours and cooled down in the furnace to room temperature for 24 hours. The drilling resistance test; the high-speed twist drill diameter of 3 mm, the rotating speed of 1000 rev/min, and the crosshead speed of 5-25 mm/min were investigated. It was found that the surface hardness from drilling resistance, normal hardness and Charpy impact resistance increased as the spheroidizing temperatures increased. The maximum surface hardness was found at the third spheroidization.

Index Terms: Triple spheroidization, Surface hardness, Drilling resistance behavior, Powder coated gray cast iron

1 Introduction

GRAY cast iron parts of manufacture amalgamating various microstructures are used, among other purposes, for the manufacture of machines including machinery utilized in the food processing industry and then coat the part with an appropriate coating material so that it can be used in a food processing environment. In the manufacture of such machine parts, a processing step employed prior to coating typically includes an annealing step to effect release of moisture and outgassing [11]. The microstructures with the fine spheroidal carbides scattered throughout the ferrite matrix, as well as the high mechanical properties. Furthermore, the eutectoid transformation temperature increases with the increase of Al, hence the newly formed lamellar pearlite is possible to be spheroidized by annealing at a higher temperature [2]. The hardness and thus the wear resistance of the cladded layer was noticeably improved due to the combined effect of the added TiC particles and the formation of hard phases during the re-solidification after the laser surface treatment [5]. Powder coating is a surface treatment using electrostatic spraying of dry powder. This microstructure treatment is typically applied to the components of gray cast iron in order to enhance the surface hardness [12] [13]. The spheroidizing treatment involving the prolonged heating of gray cast iron was studied in [2]. As illustrated in Figure 1, the heating is prolonged by keeping the temperature at the lower critical temperature (A1). The study found that a coarse globular grain texture being achieved by spheroidizing can make gray cast iron soft and particularly well suited to be machined by cutting tools [3]. That is the spheroidization was done by heating the gray cast iron to A1 and holding at this temperature for a sufficiently long time and slow cooling from 650°C [8]. This slow cooling being done in the furnace with a good insulation showed that the carbon diffusion and surface tension of the cementite can cause the formation of coarse lamellae thereafter of globular cementite [4]. In addition, the globular cementite particles produced by spherical cementite segregations within ferritic grains can form the so called globular grain structure [7]. These microstructural characteristics imply the lessening of material hardness and the enhancement of machinability. This treatment indicates the effect of cementite on the mechanical properties which could make contribution in material and process design. In this study, a spheroidizing treatment was implemented to lessen the surface hardness of gray cast iron material which has been treated by typical powder coating. The primary objective of this study is restoring ductility or removing residual stresses to improve the machinability of powder coated gray cast iron by the triple spheroidizing treatment. The mechanical behavior were investigated by using drilling test of universal testing machine, the surface hardness in powder coating area, normal hardness and Charpy impact resistance were also considered.

2 Materials Characterization

Material and Specimen Preparation

Powder coated gray cast iron having the following chemical composition (Table 1) was cut into specimens in preparation for the spheroidizing treatment and specimen testing. (Figure 2) Afterward, drilling resistance, impact resistance, surface and normal hardness tests were performed.

Table 1

Powder coated gray cast iron, chemical compositions

Content of elements, wt. (%)					
C	Si	Mn	P	S	-
3.5	2.08	0.58	0.035	0.12	
Element	Fe	C	Si	Mn	Al
Powder	Balance	3.75	2.70	0.70	1.18

(Inspection by Department of Industrial Engineering, Faculty of Engineering, Srinakharinwirot University)

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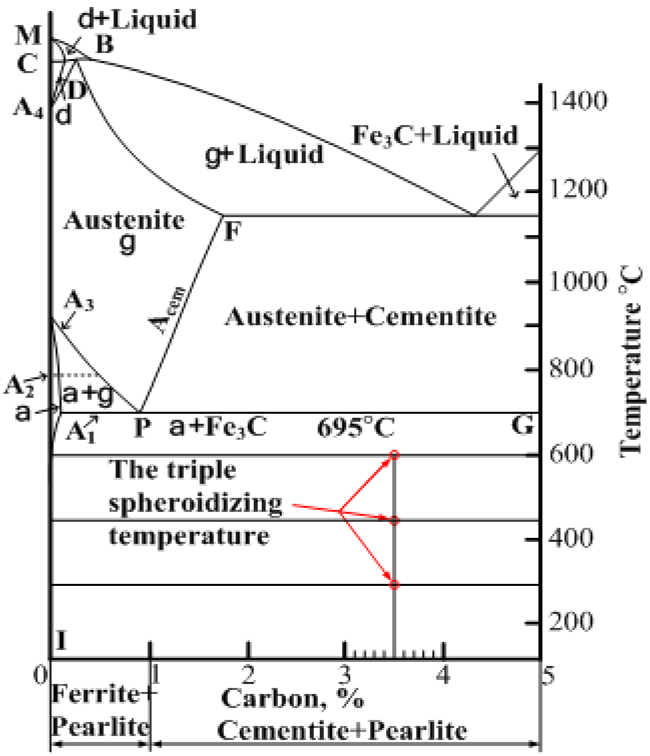


Figure 1. Part of the equilibrium diagram for this experiment.

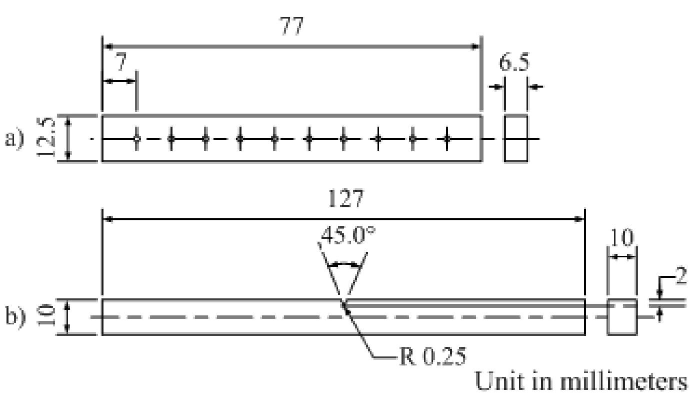


Figure 2. *Dimensions of specimens for a) drilling resistance* b) Charpy impact resistance

3 Experimental Testing

Spheroidizing treatment: The triple spheroidizing treatment was implemented (Figure 3) at 300°C, 450°C and 600°C consecutively with 6 and 24 hours of operation and relaxation time respectively. (Slowly cooling down in furnace to room temperature)

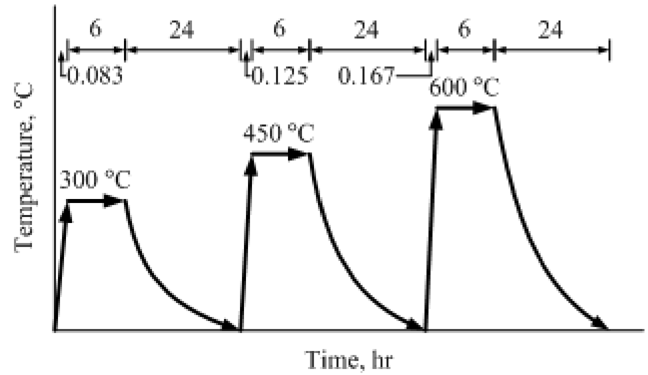


Figure 3. *Schematic illustration of the triple spheroidizing treatment conditions in this experiment.*

Microstructural analysis and testing: Optical microscopy (Nikon Epiphot 200) connected to a CCD-IRIS was utilized to examine the material microstructure (Figure 4) and also applied to observe the microstructure of the specimens. The specimens were polished and etched, DP-DUR polishing cloths with alumina powder (5% Nitric+100ml ethanol).

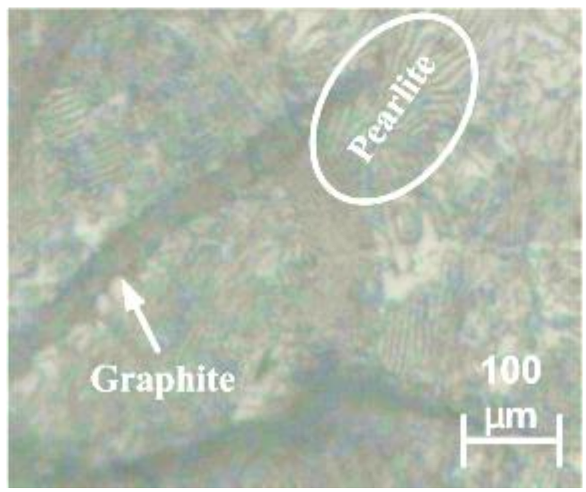


Figure 4. *The microstructure of powder coated gray cast iron is pearlite (fingerprints) and graphite (large flakes), respectively. (100x magnification)*

Hardness testing: Hardness testing of the constituents and bulk sample was performed using the Rockwell hardness tester, Affri Brevetti (150 kg). The Rockwell hardness test method consists of indenting the test material with a diamond cone indenter. The indenter is forced into the test material under a preliminary minor load usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration. When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number [6].

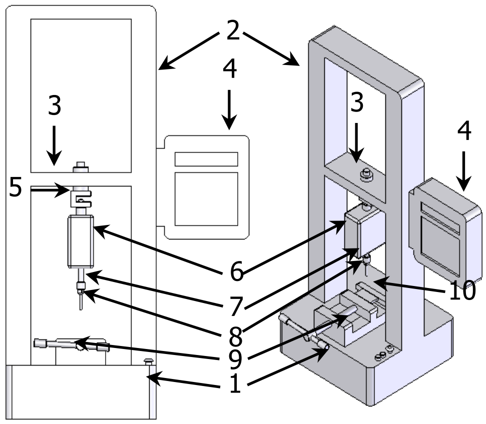
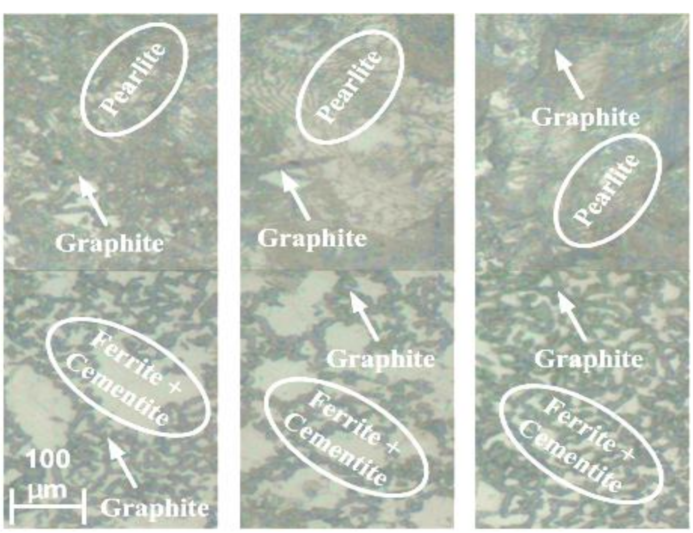


Figure 5. *Drilling resistance tests using the universal testing machine. (LR 10K, Lloyd Instrument)*

Drilling resistance testing: Drilling resistance has been measured by modifying the universal testing machine (Figure 5) using programming commands. The electric drill (6) was installed and operated at rotating speed 1000 rev/min on a load cell (5), the machine base (1) having a clamping vise (9) to hold the specimen (10), the operational test were used console commands (4) and computer commands. The high speed twist drill diameter of 3 mm (8) was tightened on the drill chuck (7). Compression test and the crosshead speed of 5-25 mm/min were selected, bring the crosshead (3) down along the vertical column (2) to the drill position near the center point of the test and set to zero. The universal testing machine is ready to run the test. Press the GO button; the LED illuminates to indicate computer control is enabled. Proceed to operate the program.

4 Results and Discussion

Microstructure observation of powder coated gray cast iron by the triple spheroidizing treatment;



6a) 6b) 6c)

Figure 6. *the microstructure observation on the triple spheroidizing treatment at 6a) 300ºC 6b) 450ºC 6c) 600ºC* (100x magnification)

The spheroidizing temperatures were 300ºC, 450ºC and 600ºC (Figure 6). The result found that the first spheroidization of 300ºC (Figure 6a), a lamellar aggregate of ferrite and cementite was formed at a temperature below the lower critical temperature (A1), the cementite in the form of pearlite changed from lamellar to spheroidal shape with random orientation. The very slow cooling down of cast iron in furnace to the original temperature influence high silicon and carbon structure to form the ferrite and pearlite matrix. In the second spheroidizing phase, When the heating reached 450ºC (Figure 6b), the ferrite and cementite eutectoid in pearlite micrograph was surrounded by pearlite in which, some large graphite flakes were form and the tiny flakes were found to have chain-like orientation. In the third spheroidizing phase, when the heating reached 600ºC (Figure 6c), the large graphite flakes increased and the tiny flake orientation was found to have more even distribution. The Rockwell hardness results show the normal and surface hardness of powder coated gray cast iron by the triple spheroidizing treatment; the spheroidizing temperatures were 300ºC, 450ºC and 600ºC. The results showed that at the first spheroidization of 300ºC (Table 2), the surface and normal hardness increased from 15.67 and 15.50 to 19.08 and 19.83 HRC respectively. These may cause by the random orientation due to the slowly cooling down to room temperature in furnace and the forming of the carbon structure in term of carbide around the powder coated surface. At the second and third spheroidization of 450ºC and 600 ºC respectively (Table 2), the normal hardness decreased from 19.08 to 12.42 and the surface hardness increased from 19.83 to 31.00 HRC. The decreasing of normal hardness may cause by the structural changing of pearlite in which the ferrite and cementite replaced the majority of pearlite. The high temperature and the longer duration increased the forming of the carbon structure in the term of carbide which could enhance the surface hardness.

Table 2

The hardness of specimen

Hardness test, HRC (the average of the test)				
Test type	Untreated	1st spheroidized	2nd spheroidized	3rd spheroidized
Normal hardness	15.67	19.08	16.92	12.42
Surface hardness	15.50	19.83	26.83	31.00

Drilling resistance tests on powder coated gray cast iron by the triple spheroidizing treatment; the spheroidizing temperatures were 300ºC, 450ºC and 600ºC. The drilling resistances of gray cast iron specimens were analyzed based on the relations between compressive load (N) and compressive extension (mm) of each crosshead speed, as illustrated in Figure 7a-7d. The Compressive extension was measured based on the distance of drilling to achieve a certain load. The results showed that, for all conditions, the drilling resistance increased as the increasing of the crosshead speed. The drilling resistance rose gradually as the increasing of spheroidizing temperatures and reached the maximum value when the compressive extension equals to a haft thickness. Untreated gray cast iron specimens (Figure 7a) had a maximum drilling resistance of 13.03 MPa, the rapid changes of drilling resistance were also considered. These could indicate the surface resistance which increased from 5.38, 5.94 to 7.36

MPa for the first (Figure 7b), second (Figure 7c) and third spheroidized (Figure 7d), respectively. Charpy impact resistance are increased, as the spheroidizing temperatures increased. Untreated gray cast iron has maximum impact strength of 1.83 MJ/m2 (Table 3).

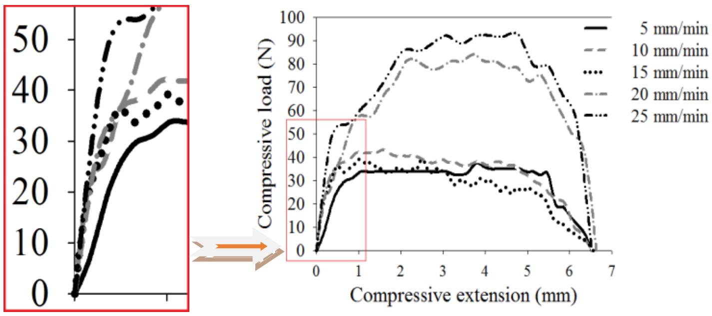


Fig. 7a. *Drilling resistance behavior of the untreated gray cast iron powder coated at the crosshead speed of 5-25 mm/min.*

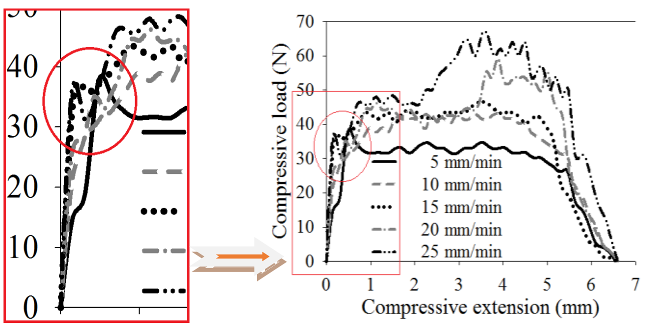


Fig. 7b. *Drilling resistance behavior of the first spheroidized gray cast iron powder coated at the crosshead speed of 5-25 mm/min.*

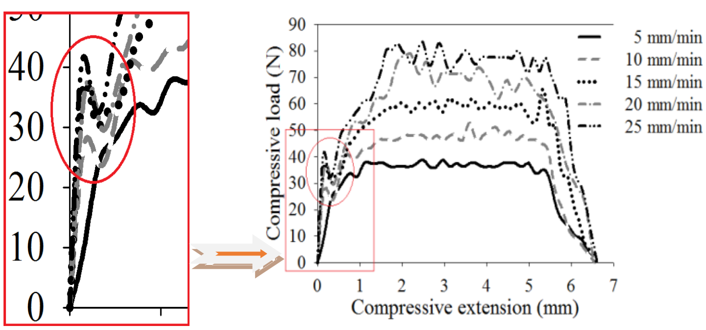


Fig. 7c. *Drilling resistance behavior of the second spheroidized gray cast iron powder coated at the crosshead speed of 5-25 mm/min.*

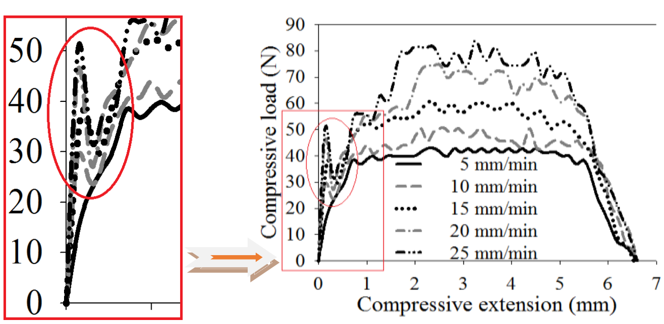


Fig. 7d. *Drilling resistance behavior of the third spheroidized gray cast iron powder coated at the crosshead speed of 5-25 mm/min.*

Table 3
The drilling resistance and Charpy impact resistance of specimen

Drilling resistance (MPa)				
powder coated cast iron	Untreated	1st spheroidized	2nd spheroidized	3rd spheroidized
Maximum drilling resistance	13.03	9.34	11.73	11.84
Charpy impact resistance (MJ/m2)				
powder coated cast iron	Untreated	1st spheroidized	2nd spheroidized	3rd spheroidized
Maximum impact resistance	1.83	1.77	1.79	1.80

5 Conclusion

The objective of this study on the influence of the triple spheroidization on surface hardness from drilling resistance (Dry drilling) of powder coated gray cast iron using universal testing machine (Compressive mode), the surface hardness in powder coating area, normal hardness and Charpy impact resistance were considered. The following conclusions can be made: The microstructural observation found tiny spheroidal graphite in the cementite grain which has more uniform orientation. The normal hardness decreased as the spheroidizing temperatures increased and the surface hardness increased as the spheroidizing temperatures increased. The maximum normal and surface hardness is 19.08 and 31.00 HRC. Drilling resistance tests, the drilling resistance increased as the spheroidizing temperatures and the crosshead speed increased. Untreated gray cast iron has maximum drilling resistance, occurred in a half thickness. Charpy impact resistance test, the Charpy impact resistance increased as the spheroidizing temperatures increased. Untreated gray cast iron has maximum impact strength. In this design of experiment, the spheroidizing treatment showed the influent on the surface hardness enhancement and the normal hardness softening. This could be applying to powder coating on the gray cast iron treatment to enhance the durability of the surface hardness and the machinability of the whole product.

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