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EFFECT OF VORTEX TECHNIQUE TO ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF THIN WALL DUCTILE IRON

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ABSTRACT

The needs of lighter automotive components have enhanced the application of thin wall casting technology on ductile iron which is known as Thin Wall Ductile Iron (TWDI). In the current research, TWDI was produced using vortex technique with different thicknesses of 5, 10 and 15mm. Vortex technique is a modern method for producing high quality ductile iron. This aims at producing TWDI with high nodularity and high mechanical properties. The shape of cast samples had a dimension of 154mm x 120mm for each plate with different thicknesses of 5, 10 and 15mm. They cut into pieces for determining the mechanical properties such as tensile, hardness and wear resistance as well as microstructures of these casted alloys. The results show that the microstructures of the three casted samples were composed of pearlite, ferrite and nodular graphite. Maximum hardness of 300 HB was obtained for 5mm thickness sample and the minimum one of 250 HB was for 15mm thickness sample. Maximum tensile strength and wear resistance were obtained for 5mm thickness sample due to existing of high amount of pearlite and the minimum values were resulted for 15 mm thickness sample. Therefore, TWDI can be considered as substitutional material of steel sheets and can produce spare parts which save cost and 10% in weight as compared to steels. [Copyright information to be updated in production process]

KEYWORDS: *TWDI, Thin Wall Casting, Vortex Technique, Light Castings Products, Ductile Iron*

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INTRODUCTION

Ductile iron has been under intensive development over the past years due to it exhibits a good combination of strength with ductility ensuring its huge application in heavy engineering industries. Nowadays, the development of ductile iron led to introduction of thin-wall ductile iron (TWDI) as a new improvement, in order to increase the strength to weight ratio and, in consequence, its competitiveness against light alloys like aluminum alloys [1-6]. The excellent combination of properties found in thin-walled ductile iron castings make them highly promising materials to be applied as substitutes for steel castings and forgings in various engineering applications [7,8]. Production costs and energy consumption of cast iron are lower than aluminum components. About 1 ton of primary Al produced by electrolysis requires from 164 to 171 GJ of energy, while 1 ton of pig iron needs about ten 10 times less (from 16.8 to 18.8 GJ). Then, secondary Al production needs at least two melting processes, while cast iron melting is normally a one-phase procedure and can be melted many times without losing quality [9]. The main problem in the production of TWDI is the cooling rate; since the thickness of TWDI is classified to be below 5 mm. The high cooling rate taking place during solidification of thin wall ductile iron castings, promotes two main changes in the microstructure namely; the precipitation of iron carbides and the increasing in the nodule count [1,5, 10,11]. Several researchers take casting design to deal with TWDI cooling rate since casting design is a free parameter. Changing in casting design will not disturb material supplies, equipment's, and process that have been established [1,3,5,12]. Other researchers studied the TWDI in order to improve the mechanical properties and the quality of castings;

J.O. Choi et al. [13] have investigated the effect of rare earth element on microstructure formation and mechanical properties of thin wall ductile iron castings. Ductile iron castings with 2, 3, 4, 6, 8, and 25mm thickness and various amount of Rare Earth elements (RE) (from 0 to 0.04%), were cast in sand molds to identify the effects of sample thickness and the content of RE% on microstructure formation and mechanical properties. The results showed that the yield strength of the samples with RE within the range investigated were lower than those of the specimens without RE. The elongation was improved with the addition of RE up to 0.03% in ductile iron castings. The additions of 0.02% RE caused a smaller graphite nodule size and a higher number of graphite nodules than those in the specimen without RE at all levels of RE addition; the nodule count decreased with increase in section size. R.C. Dommarco et al. [11,14] have studied the rolling contact fatigue resistance and wear resistance of ductile iron with different nodule counts and matrix microstructures. The research reported that thin wall ductile iron castings are being used in the industry as a way to improve the strength to weight ratio of machine parts. The high cooling rate, suffered by thin wall parts during the solidification process, promotes several microstructural changes, such as, carbide precipitation and a noticeable nodule count increment. In the current work, TWDI castings were produced by using vortex technique with different thicknesses in order to study the effect of the new method on the microstructure and mechanical properties of TWDI.

EXPERIMENTAL WORK

In the first stage of this research the investigated plates were designed with the same length but different thicknesses; the length of investigated samples was 120 mm while the width was 154 mm. The thicknesses of samples were varied between 5 mm, 10 mm, and 15 mm. In order to achieve casting design for investigated samples, the design stage was depending on the layout design as shown in Figure1. The metallic charge for ductile iron base was consisted mainly of: pig iron, steel scrap, return ductile iron scrap and ferroalloys. By adding 20% to 40% of return ductile iron scrap, and 20 % of steel, and the rest is sorrel metal (pig iron with low manganese content less than 0.1%). Then putting the charge with specific quantity inside induction furnace with 100kg capacity and medium frequency at temperature 1520 ºC. After melting process, a sample was taken from the molten metal to determine the chemical composition.

After this, the molten metal was poured inside the ladle and then treated by vortex method to get ductile iron through pouring the ladle inside a vortex machine with alloying elements such as Fe-Si which called inoculate to increase graphite flakes in microstructure and also Fe-Si-Mg. The molten metal and alloying elements were mixed like vortex and then poured inside another ladle which filled as quickly as possible, to improve the magnesium recovery, the magnesium recovery depends on metal temperature, the quantity of metal treated and the design of the ladle. After treatment of ductile iron, the molten metal was poured in to the mold quickly. After solidification of metal the castings were ejected and cut down into three different samples with 5, 10 and 15 mm thickness as shown in Figure 2 in order to study the effect of thin wall on the properties of ductile cast iron.

Extensive metallographic investigations were accomplished to study the effect of varying thickness on properties of TWDI. Spectrometer device for metal analysis was used to know the chemical composition of the investigated samples. The tensile strength and elongation of the investigated samples were evaluated using LFM-L20KN tensile testing machine. Three standard specimens were prepared from investigated samples according to dimensions shown in Figure 3.

Scanning electron microscope SEM was used after tensile test in order to evaluate the fracture surface of specimens. The hardness values of the investigated materials were measured as the average of 5 readings along the cross section surface of the specimens using Vickers HWDM-7 hardness tester. The wear test was carried out using a pin-on-ring test at different speeds by using set up shown in Figure 4.

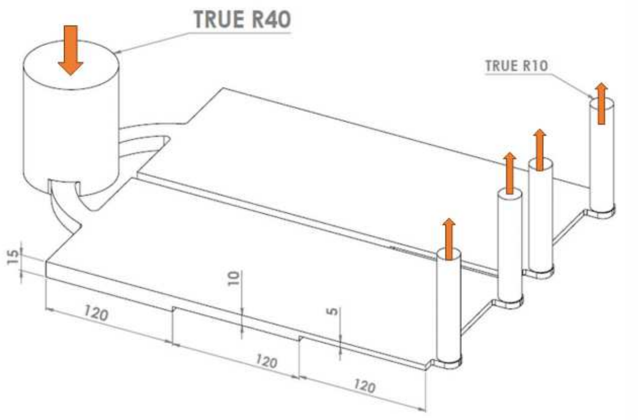


Figure 1: Casting Layout Design for Investigated Samples.

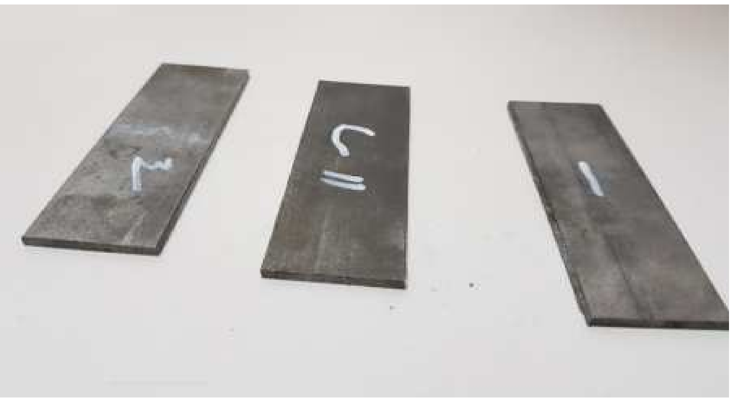


Figure 2: Investigated Samples with Different Thickness 5, 10 and 15 Mm.

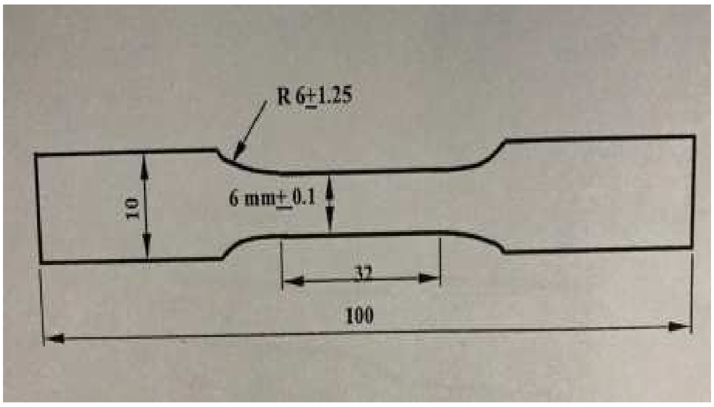


Figure 3: Tensile Test Specimen Dimensions.

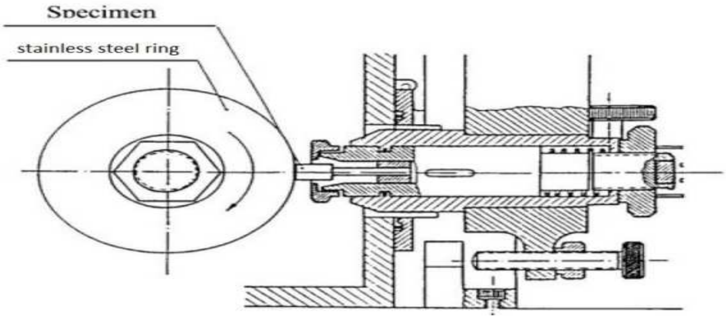


Figure 4: Diagrammatic Sketch Showing Details of Wear Test.

RESULTS AND DISCUSSION

Chemical Compositions of Samples

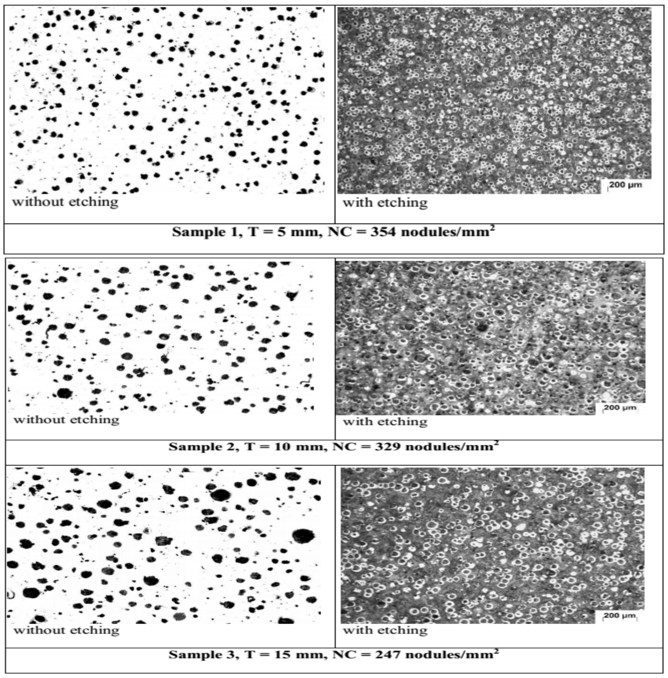
Table 1 shows the chemical composition of the investigated thin wall ductile iron according to ASTM standard.

Table 1: Specimen Chemical Composition

C	Si	Mn	S	P	Cu	Cr	Ni	Fe
3.65	2.46		0.016	0.022	0.48	0.14	0.124	rest

Microstructure Examination

Figure 5 shows the microstructures of three different samples. Each sample investigated by two different treatments, with and without etching, in order to determine the nodule count. To determine the constituents of the microstructure, the polished surface was etched using nital solution (alcohol + nitric acid). The microstructure of the studied three different thicknesses was composed of pearlite, ferrite and nodular graphite. The pearlite content was approximately exceeded 80% in all samples, as shown in Fig. 695. It can be noticed that 5mm cast sample showed the finest structure compared to the other thicknesses, this is due to the fast cooling rate of the thin wall of 5mm.



Sample 1, T = 5 mm, NC = 354 nodules/mm^2

Sample 2, T = 10 mm, NC = 329 nodules/mm^2

Sample 3, T = 15 mm, NC = 247 nodules/mm^2

Figure 5: Microstructure of the Investigated Thin Wall Ductile Iron.

Nodule Count Determination

For determining the nodule count (NC) in the three different cast thicknesses (5, 10 and 15mm), the polished samples were used without etching. As shown in Figure 6. By representing the relationship between the nodule count and sample thickness, as shown in Figure 6, the nodule counts decreases with increasing the cast sample from 354 NC (5mm) to 247 NC (15mm).

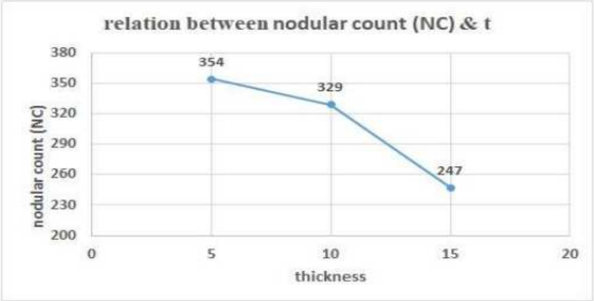


Figure 6: Relation between Thickness and Nodule Count (NC)

Hardness Results

The results of hardness test showed that when the thickness decrease the hardness increase due to increase of pearlite content as well as the fines of the structure. It is clear here that the hardness increases from 250 HB to 300 HB with decreasing the cast sample from 15 to 5 mm, this is attributed to increasing the pearlite content in the structure as well as the fines of the microstructure.

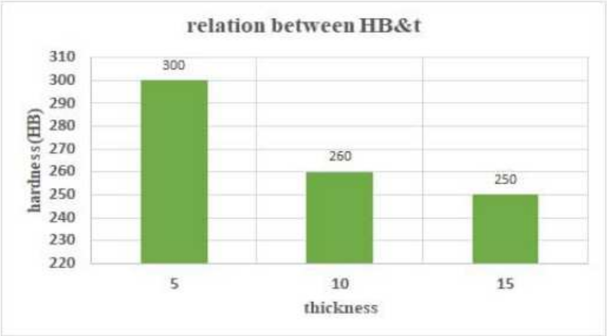


Figure 7: Relation between Thickness and Hardness.

Tensile Test Results

The tensile properties of the cast thin wall ductile iron (TWDI) with different thicknesses were determined, as given indicated in Table. 92. Maximum ultimate tensile strength of 675 MPa was obtained for 5mm cast sample and the minimum one of 660 MPa for 15mm. The yield strength was also in the same order as ultimate strength. However, the elongation percent was equal (8%) for both 5 and 10mm.maximum elongation of 10% was given for 15mm due to increasing relatively the ferrite content in the microstructure, as shown in Figs. 72-74.

Table 2: Tensile Properties of the Studied Thin Wall Ductile Iron

Sample Thickness	Ultimate Strength (MPa)	Yield Strength (MPa)	Elongation (%)
T1 = 5mm	675	620	8
T2 = 10mm	674	615	8
T3 = 15mm	660	600	10

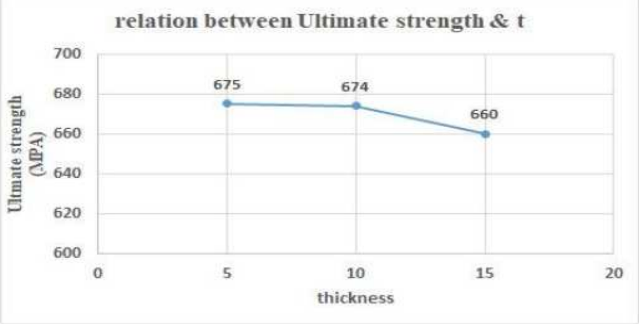


Figure 8: Relation between Thickness and Ultimate Tensile Stress.

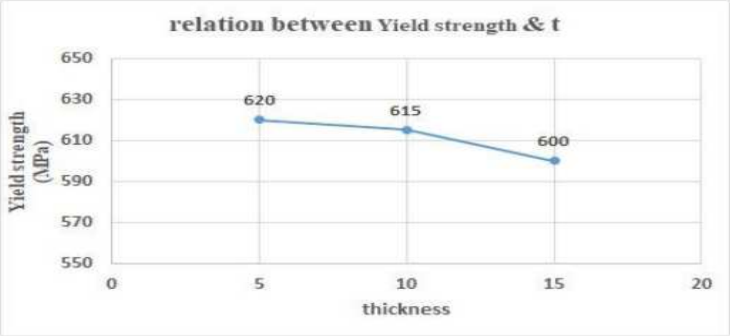


Figure 9: Relation between Thickness and Yield Strength.

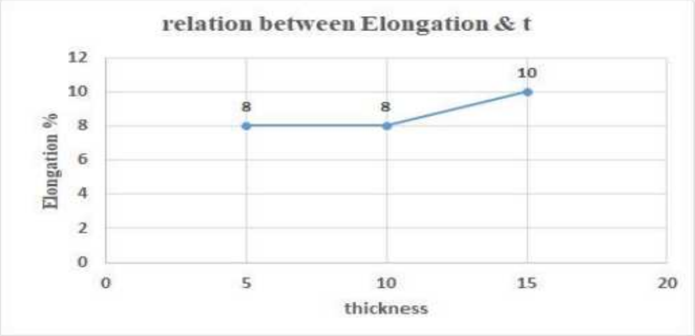


Figure 10: Relation between Thickness and Elongation.

Fractography of Tensile Samples

Figures 11-13 showed the Fractography of the fractured surface of the tensile samples. The fracture surface of the three different thicknesses showed a qusi-cleavage fracture mode. However, the thickness of 15mm showed relativity higher amount of dimples compared to the other cast samples of 5 and 10mm. These fracture surfaces features were in agreement with the obtained the results in Table 2.

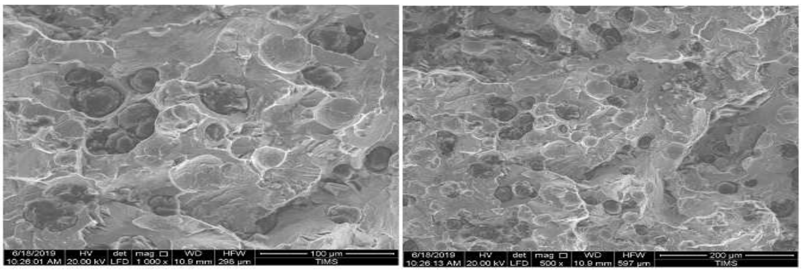


Figure 11: Fractography of Sample 5mm Thickness.

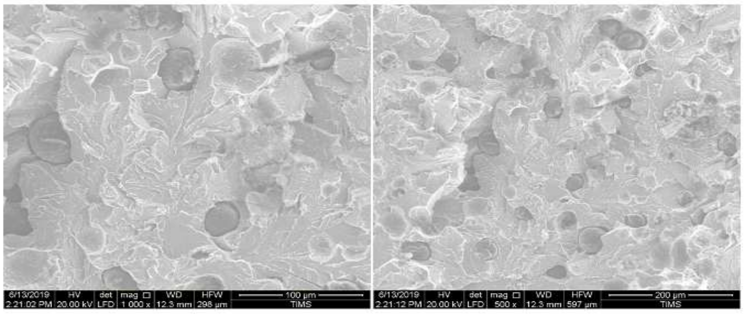


Figure 12: Fractography of Sample 10mm Thickness.

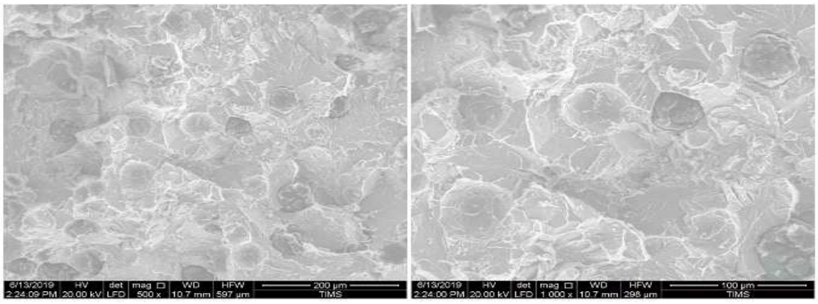


Figure 13: Fractography of Sample 15mm Thickness

Wear Resistance

Figure 14 showed the wear resistance of the investigated TWDI for thickness 5, 10 and 15 mm as a function of sliding speed in the range of 0.5 to 2 m/sec with a step of 0.5 m/sec. The wear resistance of thin cast sample of 5 mm is higher than that of 10 mm and 15 mm due to the higher amount of pearlite content in the microstructure as well as the fines of the structure. The wear results were matched with the hardness results, where the higher hardness gives higher wear resistance.

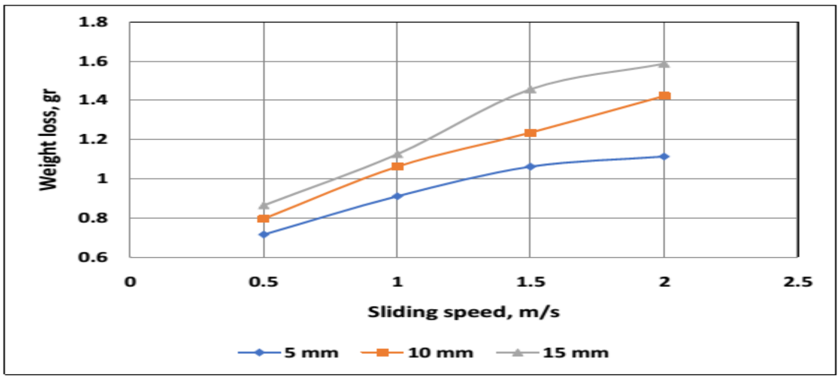


Figure 14: Wear Resistance Behavior of the Three Samples.

CONCLUSIONS

Therefore, TWDI can be considered as substitutional material of steel sheets and can produce spare parts which save cost and 10 % in weight as compared to steels. The following points can be concluded from the previous results:

- The microstructure of the three samples composed of pearlite, fearlite and nodular graphite. The most constitution of microstructure was about 80 % pearlite and the rest was ferrite.
- The nodule counts decrease from 354 to 247 with increasing the cast wall thickness.

- Hardness and Tensile strength decrease as cast thickness increases, maximum hardness value obtained was 300 HB and 675 MPa for 5 mm thickness, respectively.
- Fractured surfaces show a quasi-cleavage mode. Higher number of dimples were shown for 15mm thickness.
- Maximum wear resistance value obtained from 5mm and minimum value for 15mm thickness.

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