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Investigation of Different Developed Iron in Iron Production Companies

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Abstract- Temperature is one of the process parameters that pose great challenges in iron Production Company. This study therefore focuses on the investigation of temperature effect on the mechanical properties of the produced iron. The mechanical properties studied in this research were tensile strength, hardness, Young Modulus of Elasticity and Shear modulus. The types of Iron used in this research are Wrought Iron, Pig Iron and White cast Iron respectively. The mechanical properties of these types of Iron were determined at various temperatures which ranged from 20ºC to 920ºC respectively. From the investigation, the optimal tensile strength of Wrought Iron, Pig Iron and White cast Iron were 1442MPa, 1340MPa and 1200MPa at temperature of 20ºC, 20ºC and 820ºC respectively. The optimal Young Modulus of Elasticity of Wrought Iron, Pig Iron and White cast Iron are 98.2GPa, 93.1GPa and 87GPa at temperature of 20ºC, 20ºC and 20ºC respectively. The optimal Shear Modulus of Wrought Iron, Pig Iron and White cast Iron are 77.5GPa, 74.5GPa and 65.3GPa at temperature 20ºC, 272.5ºC and 520.2ºC respectively**.** The optimal Rockwell Hardness Number of Wrought Iron, Pig Iron and White cast Iron are 60, 56 and 60 at temperature of 20ºC, 70ºC and 570ºC respectively. The results obtained shows that temperature have great effect on the mechanical properties of the iron produced in Iron manufacturing industries.

Keywords Iron, Manufacturing industries, Mechanical properties, Optimal, Temperature.

1. Introduction

Improper investigation of process parameters in the production of Iron had been a great challenge in ensuring consistency in the mechanical properties of produced Iron in Iron production companies. Iron is one of the major metals used in engineering design and construction works. Iron possesses excellent mechanical properties such as tensile strength, hardness, high impact strength, high shear modulus of rigidity and high modulus of elasticity. Iron is used in combination with other metals and non-metals, such combination is called alloy, and this is due to its excellent properties. According to Allain et al and Bouaziz et al [1, 2, 3], they stated that Fe-Mn alloys have attracted significant attention due to their excellent mechanical properties such as combination of high strength, high elongation and excellent mechanical work hardening ability'. In the study of Fu et al; Ghasri et al and Ueji et al [4, 5, 6], 'they examined the effect of temperature on steel, they concluded that increase or decrease in temperature have significant effect on the production of steel and other iron alloyed materials'. According to Wang et al [7, 8], they stated that the corresponding mechanical properties and deformation mechanism of Iron related alloys depend on the types of element or material added in the alloy as well as the deformation temperature. According to Wang et al [9], they examined that the refined structure of Iron and its alloy could increase the yield strength while the elongation decreases; they further stated that this causes different mechanical properties in Iron and Iron related alloys. Shterner et al., [10, 11] 'examined the temperature effect on Manganese and the effective method that could be adopted to improving the mechanical strength and ductility of high Manganese steels by tailoring the microstructure; they further stated that the percentage of manganese in the composition have some significant influence on the mechanical properties of the alloy'. 'Wang et al., [12] used cold rolling and annealing to design Fe-34.5Mn-0.04C steel to form a composite structure comprising recovered and recrystallized structures, the resulting steel demonstrated a good combination of strength and ductility, along with good work hardening ability'. 'Wu et al. [13] reported that the lamellar structure of pure titanium would lead to the same strength as that of the fine-grained structure, they further observed that coarse grain structure had similar effect of the elongation of the material'. Similarly, 'the interstitial free steel, as reported by Zhang et al. [14], would also demonstrate good mechanical properties attributing to the lamellar structure, the formation of deformed twins could inhibit the movement of dislocations, as well as reduce the average free path of dislocations, while producing a dynamic Hall–Petch effect'. The influence of temperature on the forming behavior of an aluminum/polypropylene/aluminum (APA) sandwich sheet was studied by Wu et al., and Zang et al., [13, 14], 'according to their study, shear and tensile tests were performed to determine the mechanical properties of the laminate, they also observed that the component materials is a function of process temperature. The forming limit diagram (FLD) of the laminate was established for two different temperatures, and its spring back behavior was examined in four-point bend and channel bend tests [14]'. Cup forming tests were performed at various test temperatures to determine the limiting drawing ratio (LDR) and the tendency for wrinkling at these temperatures. Although there was only a minor influence of temperature on the mechanical properties and the FLD values of the laminate, 'the bend test results reveal that spring back can be reduced by forming at higher temperature. The decreasing strength of the core material with rising process temperature led to an increased tendency of the laminate to wrinkle in the heated cup drawing tests [14]'.

This research focused on the investigation of different developed iron in iron production companies

2. Materials and Methods

The materials used in this study are wrought Iron, pig Iron and White Cast Iron. These materials were subjected to various temperatures ranging from 20ºC to 920ºC at an interval of 50ºC, and there after allowed to cool. These materials were evaluated for mechanical properties at various temperatures.

2.1. Method of Data Collection

The various types of Iron produced which were wrought Iron, pig Iron and White Cast Iron were heated to various temperature ranging from 20ºC to 920ºC at an interval of 50ºC. At these temperatures, the mechanical properties of produced Iron such as tensile strength, young modulus of elasticity, shear modulus and Rockwell hardness were determined at each temperature.

2.2. Evaluation of Produced Iron for Mechanical Strength at Various temperatures

The produced wrought Iron, pig Iron and White Cast Iron were evaluated for mechanical strength (tensile strength, young modulus of elasticity, Rockwell hardness and shear modulus) using Equation 1 to 4 respectively [10].

$$\text{Tensile strength} = \frac{\text{Maximum Load}}{\text{Original Cross – Sectional Area}} \qquad (1)$$

$$\text{Young's Modulus of Elasticity} = \frac{Stress}{Strain} = \frac{FL_o}{L_m - L_o} \qquad (2)$$

Where F = applied force, l_o= Original length; l_m = Final length

$$\text{Shear Modulus} = \frac{\text{Shear Stress}}{\text{Shear Strain}} = \frac{\frac{F}{A}}{\frac{x}{y}} \qquad (3)$$

Where F = applied force: A = Cross-sectional Area; x = Extension; y = Original length;

$$\text{Rockwell Hardness Number} = N - \frac{d}{s} \qquad (4)$$

Where d=depth from the zero load point; N and S = scale factors which depend on the test scales used.

3. Results and Discussion

Figure 1 - 4 shows the effect of temperature on the tensile strength, young modulus of elasticity, shear modulus and hardness of produced Iron (Wrought Iron, Pig Iron and White cast Iron) respectively.

3.1. Discussion of Results

3.1.1. Effect of Temperature on the Tensile Strength of Produced Iron

In figure 1, as the temperature increases the tensile strength decreases continuously for wrought iron and pig Iron until the tensile strength became the same or so close at a temperature range of 580ºC to 770ºC. Moreover, as the temperature increases for White cast Iron, the tensile strength decreases till a temperature of 353ºC, after this temperature, further increase in temperature results to an increase in tensile strength till a temperature of 832ºC. This is because at high temperature, White cast Iron structure re-crystallizes; hence, it is heat treated, this resulted to a higher tensile strength at higher temperature. After 832ºC, the tensile strength of white cast Iron decreases due to molecular break-down (molecular degradation). From the investigation, the optimal tensile strength of Wrought Iron, Pig Iron and White cast Iron were 1442MPa, 1340MPa and 1200MPa at temperature of 20ºC, 20ºC and 820ºC respectively. In addition, at higher temperatures, the internal energy of atoms is high. As a result, the atoms of the material vibrate more vigorously with high thermal agitation. When these agitations are high the movement of dislocations (movement represent ductility of material) is become easy. It requires a very less stress to tear the dislocations from their equilibrium positions. Therefore, materials exhibit low yield and ultimate strengths at high temperatures.

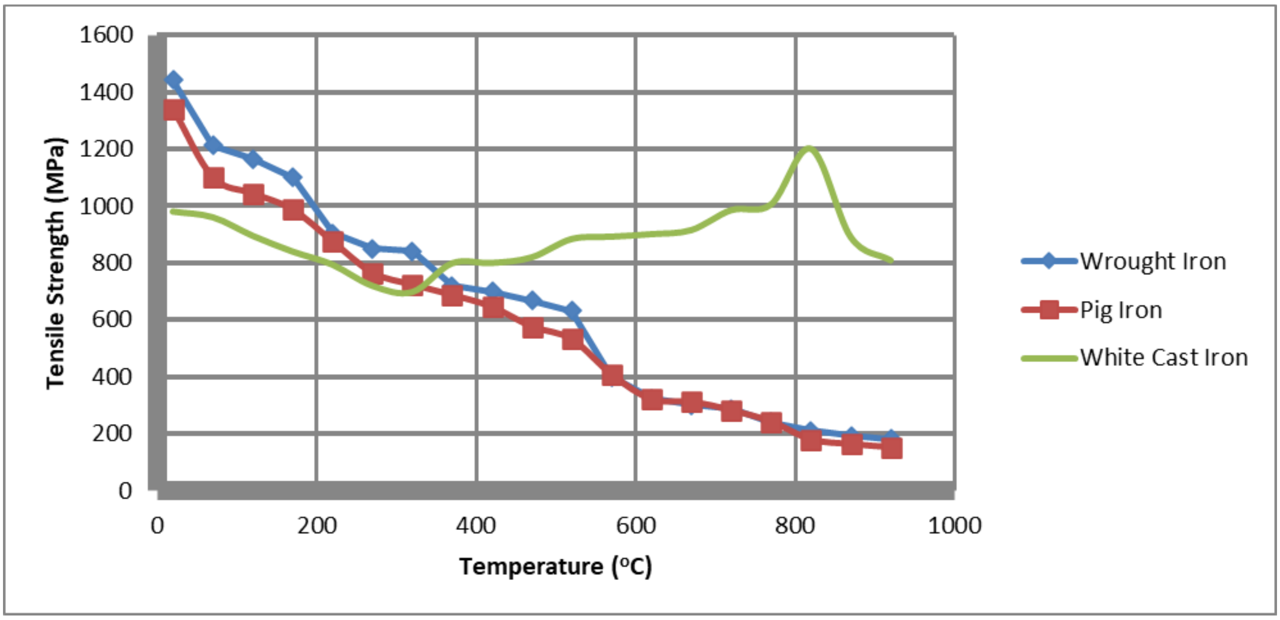

Fig. 1. Graph of the Effect of Temperature on the Tensile Strength of Produced Iron.

3.1.2. *Effect of Temperature on the Young Modulus of Elasticity of Produced Iron*

In figure 2, as the temperature increases from 20°C to 920°C , the Young modulus of elasticity decreases continuously for wrought iron, pig Iron and White cast Iron respectively. The optimal Young Modulus of Elasticity of Wrought Iron, Pig Iron and White cast Iron are 98.2GPa, 93.1GPa and 87GPa at temperature of 20°C, 20°C and 20°C respectively (figure 2). The continuous decrease in the Young modulus of elasticity as the temperature increases is due to molecular break-down (molecular degradation) which results from the movement of atoms in Produced Iron as temperature increases causing dislocation in material, hence lowering the Young modulus as the temperature increase. Moreover, the vibration in the atomic crystal structure of Iron increased as the temperature increases, hence, increase in temperature in the production of Iron increases the atomic distance and decreases atomic force, and this resulted to decreased modulus of elasticity of produced Iron.

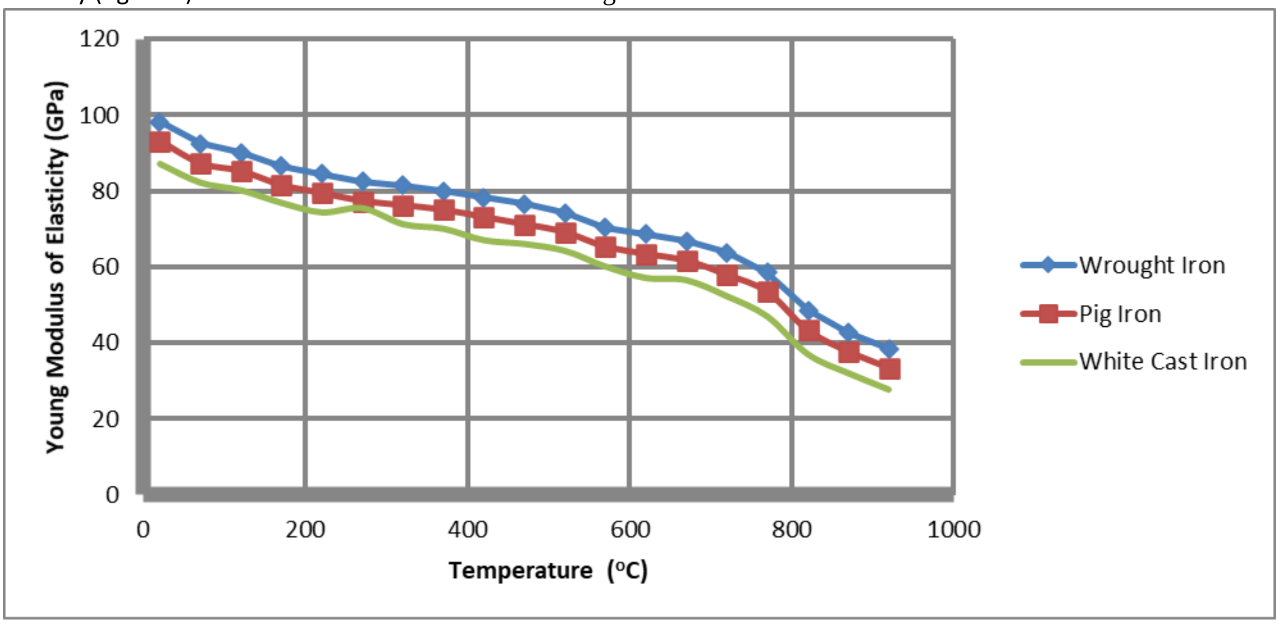

Fig. 2. Graph of the Effect of Temperature on the Young Modulus of Elasticity of Produced Iron.

3.1.3. Effect of Temperature on the Shear Modulus on Produced Iron

In figure 3, as the temperature increases from 20°C to 920°C , the Shear modulus decreases continuously for wrought iron and pig Iron until 220°C, after which the Shear modulus of pig Iron rises due to re-arrangement of atoms in Iron structure (recrystallization of atoms) as the temperature increases. The optimal Shear Modulus of Wrought Iron, Pig Iron and White cast Iron are 77.5GPa, 74.5GPa and 65.3GPa at temperature 20°C, 272.5°C and 520.2°C respectively (figure 3). The continuous decrease in the Shear modulus for wrought Iron and pig Iron as the temperature increases is due to molecular break-down (molecular degradation) which results from the movement of atoms in Produced Iron as temperature increases causing dislocation in material, hence lowering the Young modulus as the temperature increase The situation of shear modulus of white cast Iron is slightly different from that of wrought and pig Iron, for white cast Iron, as the temperature increases, the shear modulus of white cast Iron increases due to the re-crystallization of atoms as temperature increases until a temperature of 520°C after which shear modulus of white cast Iron decreases due to molecular break-down (molecular degradation) of the atoms of white cast Iron. Moreover, the vibration in the atomic crystal structure of Iron increased as the temperature increases, hence, increase in temperature in the production of Iron increases the atomic distance and decreases atomic force, and this resulted to decreased shear modulus of produced Iron.

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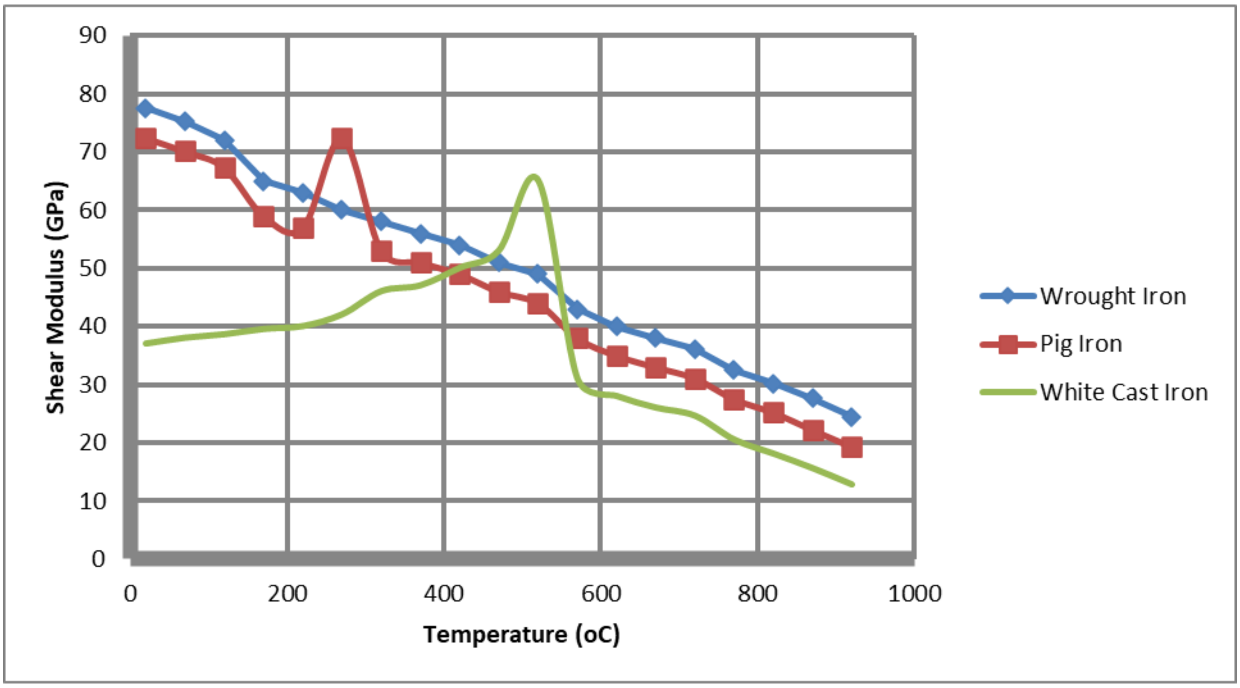

Fig. 3. Graph of the Effect of Temperature on the Shear Modulus of Produced Iron.

3.1.4. Effect of Temperature on the Shear Modulus on Produced Iron

In figure 4, as the temperature increases from 20°C to 920°C, the Rockwell Hardness Number decreases continuously for wrought iron and pig Iron while Rockwell Hardness Number for White cast Iron decreases from a temperature of 20°C to 270°C after which it increases from temperature of 270°C to 570.5°C and after which decreases. The optimal Rockwell Hardness Number of Wrought Iron, Pig Iron and White cast Iron are 60, 56 and 60 at temperature of 20°C, 70°C and 570°C respectively. The continuous decrease in the Rockwell Hardness Number as the temperature increases is due to molecular break-down (molecular degradation) which results from the movement of atoms in Produced Iron as temperature increases causing dislocation in material, hence lowering the Young modulus as the temperature increase. Moreover, the results obtained compared favorably with the results obtained by Wang *et al* and Allain et al with a Rockwell Number value of 40 and 54 for Laminated Fe-34.5 Mn-0.04C Composite and High Manganese Austenitic Steel respectively.

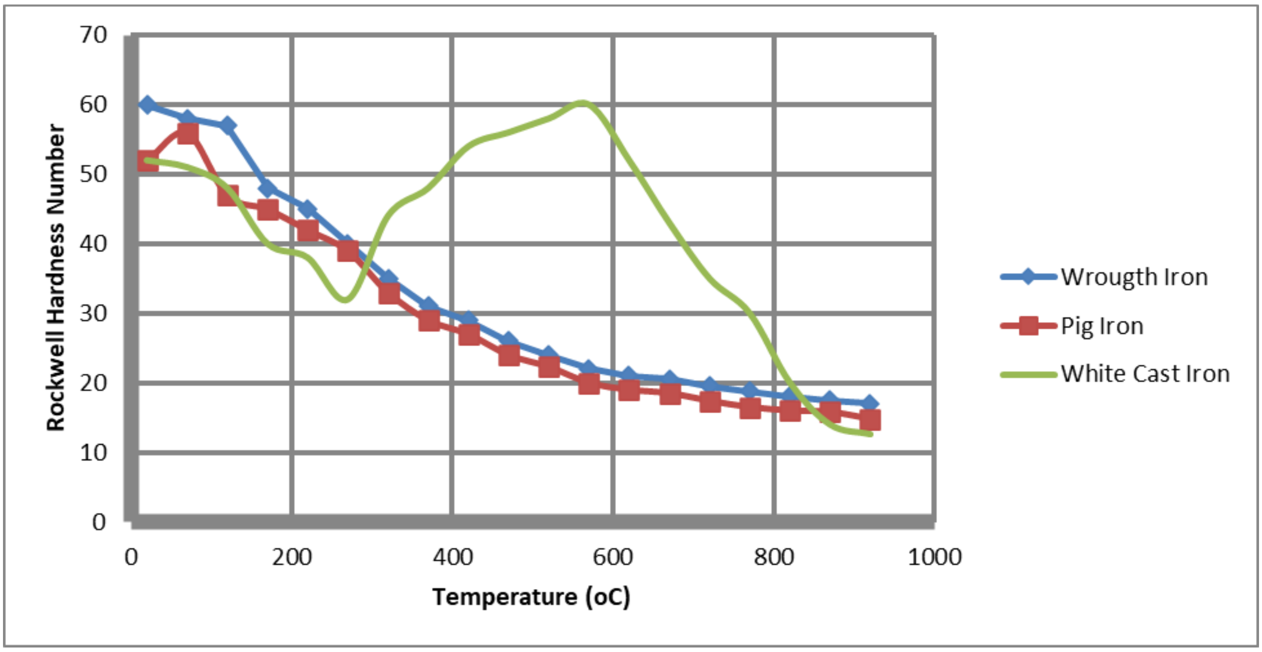

Fig. 4. Graph of the Effect of Temperature on the Hardness of Produced Iron.

4. Conclusion

The investigation of temperature effect on the mechanical properties of the produced iron had been achieved. The mechanical properties studied in this research were tensile strength, hardness, Young Modulus of Elasticity and Shear modulus. The types of Iron used in this research are Wrought Iron, Pig Iron and White cast Iron respectively. The mechanical properties of these types of Iron were determined at various temperatures which ranged from 20°C to 920°C respectively. From the investigation, the optimal tensile strength of Wrought Iron, Pig Iron and White cast Iron were 1442MPa, 1340MPa and 1200MPa at temperature of 20°C, 20°C and 820°C respectively. The optimal Young Modulus of Elasticity of Wrought Iron, Pig Iron and White cast Iron are 98.2GPa, 93.1GPa and 87GPa at temperature of 20°C, 20°C and 20°C respectively. The optimal Rockwell Hardness Number of Wrought Iron, Pig Iron and White cast Iron are 60, 56 and 60 at temperature of 20°C, 70°C and 570°C respectively. The optimal Shear Modulus of Wrought Iron, Pig Iron and White cast Iron are 1442, 1340 and 1200 at temperature of 20°C, 20°C and 820°C respectively. The results obtained shows that temperature have great effect on the mechanical properties of produce.

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