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Analysis of the Effect of Surface Finish, Carburizing and Nitriding on the Impact Energy absorbed by Medium Carbon Steel

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ABSTRACT: *Impact energy absorbed signifies the toughness strength of any material. The value relates to the wear resistance of the material. The material of Interest in this study is Medium Carbon Steel. Spectroanalysis was carried out on the sample to determine the material composition concentration. Lathe machine was used to machine Samples of scale sizes 3 mm, 5 mm, 7 mm, 8 mm, 9 mm, 10 mm. Carburizing and surface finishes such as turning, grinding and polishing were done on the samples. The results show that the impact energy absorbed is directly related to the scale sizes. Hence, Impact energy absorbed for Medium Carbon Steel is directly proportional to the sample scale sizes otherwise known as the Scale Factor.*
KEYWORDS: *Impact, Surface Finish, Carburizing, Nitriding,Steel.*

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I. INTRODUCTION

Toughness is a measure of material ability to resist impact load. Basically toughness is a balance of strength and ductility. The essence of the tests was to determine the degree and effect of fracture toughness on Carburizing and Scale Size variations. The fracture toughness is a measure of resistance to impact fracture. The toughness ought to be enough for the metal to withstand the formation of Fatigue cracks without failing. Material Strength increases usually with decrease in toughness. The desire for high strength and high toughness means it will be necessary to migrate to a different alloy that will satisfy such requirement. As the Fracture toughness drops, there is a visible decrease in the material ability to withstand its load before fracturing. Low fracture toughness means a low ductilityCarburizing is the addition of carbon to the surface of low-carbon steels at temperatures (generally between 800 and 900 ^oC) at which austenite, with its high solubility for carbon, is the stable crystal structure. Selection of carbon potential also depends on the carburizing response of particular steel (Parrish and Harper, 1985). Obiukwu *et al* (2014) in his work on fatigue test with 10 mm scale revealed thatimpact values obtained after carburizing for turned, grinded and polished are 9.25 J, 12.2 J, and 20.67 J respectively. Case depth of carburized steel is a function of carburizing time and the available carbon (carbon potential) at the surface. In Cheng and Laird (2007) work, it was demonstrated that micro cracks commence in the form of slip bands within a grain.Dexter *et al* (2013) defined fracture as rupture in tension or rapid extension of a crack which leads to gross deformation, loss of function or serviceability, or complete separation of the component. When fracture critical cracks are detected in mechanical components and structures, several methods are employed to arrest or stop them from further growth or propagation. According to Robert (2016) "Contemporary trends to reduce the consumption of materials in the construction of machines and devices require the use of high-strength, and therefore materials which are generally more fragile and susceptible to fatigue. Tawanda *et al* (2006) identified developed number of metal crack detection techniques to include human sense examination, liquid penetration method, ultrasonic testing, radiographic imaging, and magnetic particle inspection and eddy current testing, which are all non-destructive testing techniques. Various types of cracks exist in metals and the common categories include cooling, hot, solidification, centreline, crater, liquidation (hot tearing), grinding, pickling, heat treatment (quenching), machining tears, plating, fatigue, creep, stress corrosion, and hydrogen cracks.Obiukwu *et al* (2016) in their results from the tensile tests impact tests and hardness tests showed that the mechanical properties variate at every heat-treatment conditions.In their study on fatigue of carburized steels, Farfan *et al*. (2004), reported a general trend of endurance limit improvement with increasing depth of case. In another study, Asi *et al.* (2009), reported degradation in fatigue performance plus an increasing carburization temperature, due to unfavourable distribution of residual stresses within the carburized case. Woods *et al*. (1999), suggested that favourable modification in stress field could enhance the performance of machine elements such as gears, which are subjected to bending fatigue at their normal operation. Asi *et al.* (2007), divided the standard fatigue test specimens into three sets and exposed them to a different type of heat treatment by changing the parameters such as carburizing temperature, carburizing time and holding time at 850°C. The study revealed that the more depth of case leads to greater depth of oxidized surfaces, in-turn it enhances the non-martensitic transformations, which greatly affects the distribution of residual stresses and leads to a lower fatigue life.Osam (2006) conducted failure analysis of failure of a diesel engine crankshaft used in truck made of ductile cast iron. It was observed that it break into 2 pieces at the crankpin portion. The crankshaft was hardened using induction method. He conducted Failure analysis including micro-hardness measurement, photo documentation, chemical analysis, tensile testing, visual examination, and metallographic examination. The outcome revealed that the material was EN-GJS-700-2 ductile cast iron as tempered and inducted hardened condition. Examination of failure zones was done using Scanning Electron Microscope. It was revealed that the absence of hardened case in fillet region induced fatigue start and caused failure prematurely.

II. EXPERIMENTAL PROCEDURE

Medium Carbon Steel of 0.320 Carbon content was used in this work. Specimens' scale ranged from 3 mm, 5 mm, 7 mm, 8 mm, 9 mm and 10 mm for the centre- grooved diameters were machined using the Lathe machine. Spectroanalysis was done to confirm the element concentration.Carbolite Muffle furnace with a thermocouple was used to regulate the temperature heat treatment. Materials to be carburized were placed in a metal box covered with Anthracite Coal in powdered form as main source of Carbon. This powdered Coal was mixed with Barium Carbonate in about 15 % - 35 %. A fitted Lid was used to close top box and placed in a Carbolite Furnace at a temperature of 860^0C for a period of 5 hours 20 mins, after which the box was removed and hardening was achieved with a high Carbon surface layer obtained from quenching to a martensite state known to have a case with good wear and Fatigue resistance and covering a tough and less Carbon Steel core. The hardened specimen was finally washed and dried ready to be tested.Nitriding of specimen was done under atmosphere of hydrocarbon such as methane gas mixed with ammonia (NH_3). It was allowed to cool in the atmosphere and not quenched. It did not involve heating to the Austenite state and quenching to form Martensite as done in carburizing.Izod impact test was conducted on prepared samples using Izod impact tester to obtain the degree of fracture toughness.

III. RESULTS AND DISCUSSION

Element Concentration analysis was done on the medium carbon steel to reveal the element compositions as presented in table 1 below.

Table 1 Element Concentration Report by Universal Steel Ltd.

Elements	C	Si	Mn	S	P	Cr	N	Al	Fe	Ti
Composition	0.320	0.203	0.514	0.038	0.003	0.215	0.093	0.046	98.255	0.006

The analysis shows clearly that the material is undoubtedly a Medium Carbon Steel with some other vital micro element composition.

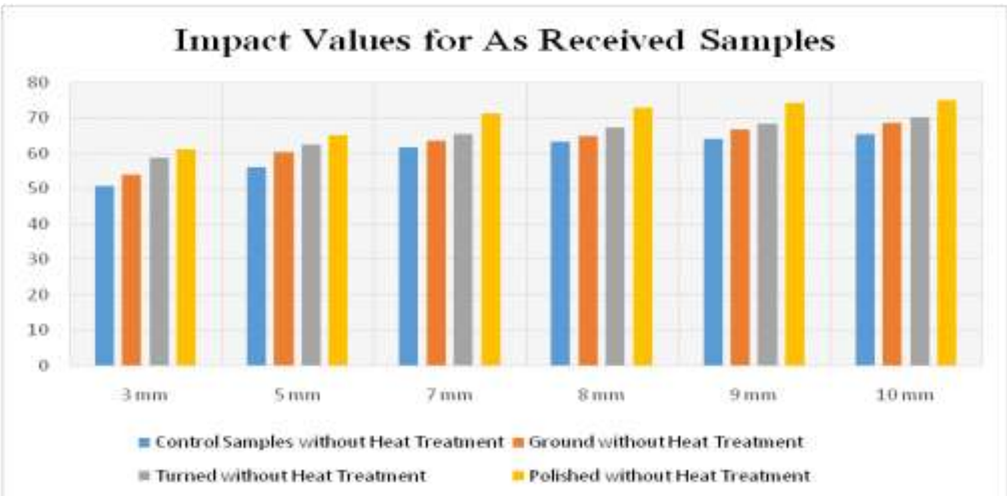

Figure 1 Effect of Surface Treatment on the Impact Value of as Received Samples

The impact energy is a measure of the energy absorbed by material before fracture. It aim at determining the degree of fracture toughness. In figure 4, the samples were not heat treated but were subjected to different surface finishes such as the control, ground, turned and polished. The sample scale sizes revealed that the control samples (as received) absorbed less energy before fracture while those polished without heat treatment absorbed more energy indicating it's high toughness. This is due to the low surface asperities that is usually a source of low stress concentration. Low stress concentration usually reduces fracture. Comparing the energy absorbed values for the samples scale sizes, control samples had 50.56 J, 56.03 J, 61.51 J, 63.24 J, 63.92 J, 65.46 J and for Polished without heat treatment 61.04 J, 65.08 J, 71.20 J, 72.80 J, 74.04 J, 75.03 J respectively. It shows that polished without heat treatment absorbed more energy before fracture than others.

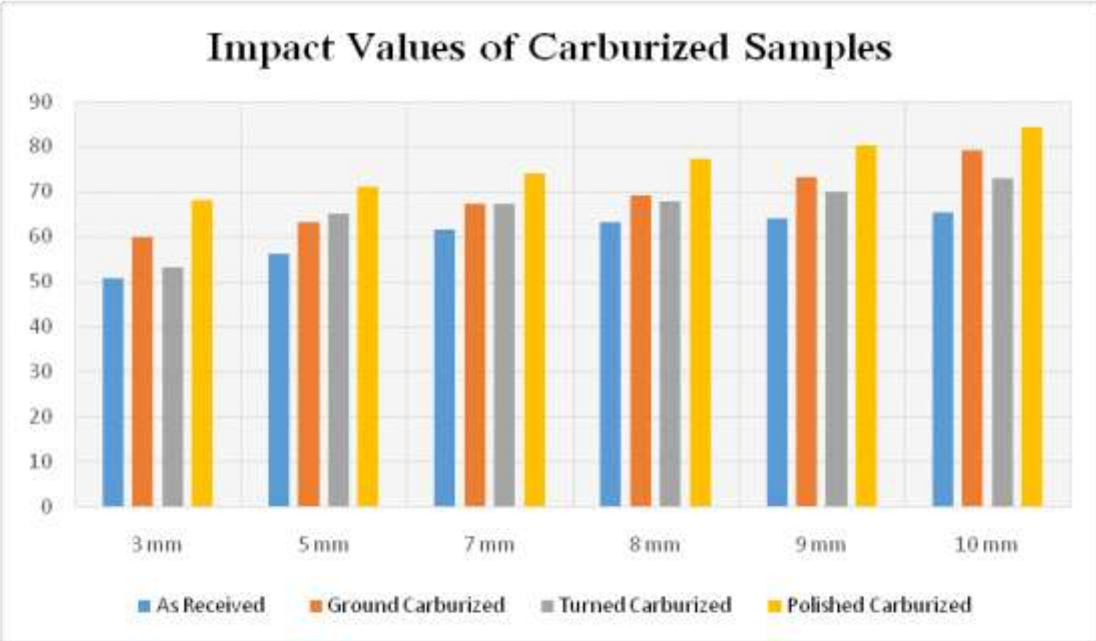

Figure 2 Effect of Carburizing Heat Treatment on Impact Value of Samples

In Figure 2, it is noticed that a similar trend occurred as in figure 1 above. However the effect of Carburizing was observed clearly. It was noticed that for all surface finish, there was a higher impact energy absorptions compared to the control samples without heat treatment. Comparing the values for without heat treatment and carburized samples, it is revealed that carburized surfaces absorbed more impact energy due to carbon diffusion that occurred. This could be traced to collapsing of asperities which will eventually lead to stress concentration reduction.

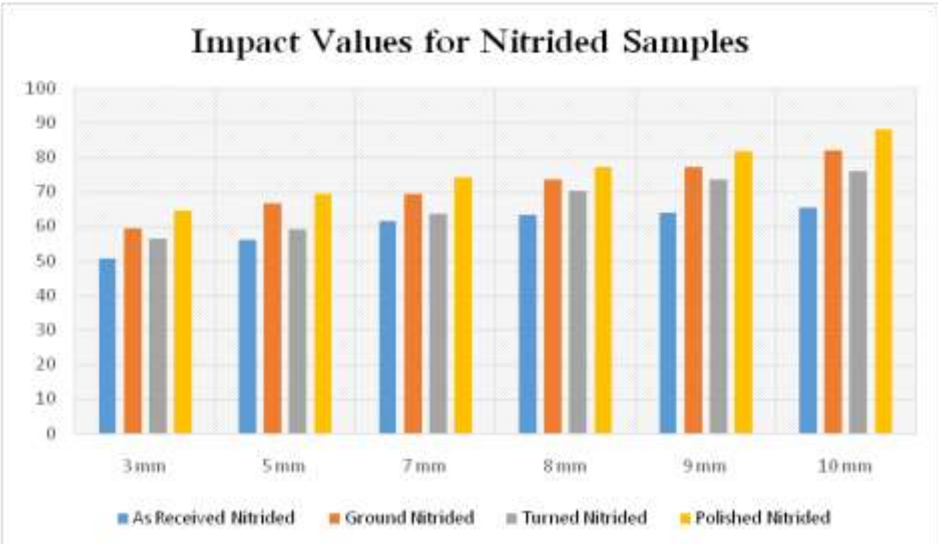

Figure 3 Effect of Nitriding Heat Treatment on Impact Value of Samples

In Figure 3, it is observed in all scales that the impact energy absorbed (in order of increase) is as follows Turned Nitrided, Ground Nitrided and Polished Nitrided. For Polished Nitrided, the Impact energy absorbed for the scale sizes respectively are 64.41 J, 69.28 J, 74.21 J, 77.11 J, and 87.91 J. In Figure 3, it is clear that Turned Nitrided Samples had a lower energy absorbed. This signifies low toughness compared to Ground and Polished Nitrided samples.

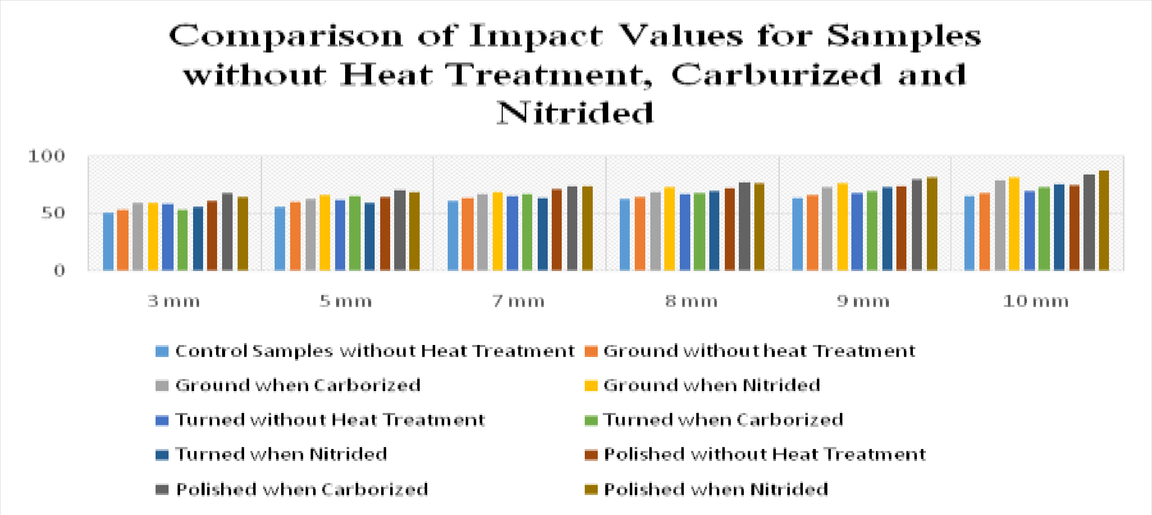

Figure 4 Effect of Heat Treatment and Surface Finish on Impact Value of Various Scale Sizes.

Comparing the impact energy values as presented in figure 4 above, it was noticed on average that Nitrided Scale sizes absorbed more impact energies than Carburized and as received (control) samples scale sizes. This is indicative that Nitrided Scale Samples are tougher than Carburized scale samples.

IV. CONCLUSIONS

The results obtained showed that increase in scale sizes affects the degree of material toughness. The more the scale increase the more the absorbed energy. Comparing different surface finish and heat treatment type the material was subjected to, it revealed that Polished Nitrided samples absorbed 87.91 J for 10 mm scale size more than 84.21 Jfor Polished Carburized samples with 10 mm sample. It points to a conclusion that impact energy absorbed is a function of increment of scale sizes. Hence, Impact energy absorbed for Medium Carbon Steel is directly proportional to samples scale sizes.

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