

# The Study of the Impact of Nano Carbon Additives on Astm A53 Mild Steel During Machining

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**Abstract.** In the world today, most of the treated steels were done using chemicals which in turn degrades rapidly. This study developed treated metal from ASTM A53 mild steel using pulverized palm kernel shell as carburizer and egg shell as energizer due to their high carbon and calcium carbonate content. Samples of hundred (100) pieces of ASTM A53 mild steel with dimensional size of 100 x 30 mm each were used. The elemental composition of the sample was checked using UV-VIZ spectrometric machine. Four sets of steel boxes were fabricated in the dimensions of 200 x 50 x 200 mm with two faces detachable and small extension for carrying the boxes at high temperature. Prepared samples buried in pulverized carburizer and energizer at a mixed percentage ratio of 80 to 20 were put together in a muffle furnace (2,500°C max) for case hardening at different holding temperature and time of (HT- 60, 90, 120 and 180 minutes) and (CT- 950, 1000, 1050, 1100°C). This procedure was repeated severally with varying holding time and temperatures. The initial experiment started from 950°C and rose up to 1100°C. The hardness for surface, interface and core were taken using hardness tester. Surface hardness of 139.4 HV at holding temperature 980°C and time 180 minutes gave best increase of 43% over the control of 79.7 HV while hardness at interface and core were 146 HV and 147 HV with percentages increase of 9 and 15.3 was achieved. The findings in this study also confirmed that waste materials with some element of carbon can be used to replace foreign chemicals intended for the same purpose.

**Keywords:** carburization; ASTM A53 Steel; Carbon additives; palm kernel shell; eggshell. Hardness

## 1. Introduction

The term steel is typically interpreted as meaning an iron-based amalgam containing carbon and steels of under 0.25% carbon (regularly alluded to as gentle steel) have to some degree higher quality close to the upper carbon level. Low carbon steel also called mild steel has lower carbon content than other steels and so naturally it is easier for it for cold-forming processes to be applied to it due to their soft and ductile nature. Low carbon steel becomes a reasonable choice because of its low cost and ease of handling especially when strength is not the most important factor in consideration [1-2]. Medium carbon steels have great machining qualities, and one of the more famous evaluations utilized as a part of machined steel item is AISI 1045. AISI 1045 can likewise be solidified by heating the material too roughly 820-850C (1508 - 1562 F) and held until the point that the material achieves a uniform temperature. It ought to be drenched for one hour for every 25 mm area of material and in this manner cooled in still air [3]. High carbon steels are those with carbon substance in the vicinity of 0.60% and 1.4% of the general weight. The composites in this specific class constitute the most grounded and hardest inside the three gatherings, yet they are additionally the minimum pliable. The essential room temperature structure of iron and steel is called "Ferrite" or alpha iron, and has a body focused cubic (BCC) precious stone structure [4-5]. Ferrite can break up to .0025% carbon (by weight—builds dependably utilize weight not particle %); any additional carbon introduce accelerates out as iron carbide, which turns out to be a piece of the microstructure and expands quality. Over 912C (1674F) Iron changes to a face focused cubic (FCC) structure called Austenite or gamma press, which can break up considerably more carbon—up to 2%. The change from Austenite to Ferrite gives the premise to steel heat treatment [6]. Heat treatment is a procedure that includes a blend of time-controlled heating and cooling operations of metal without changing the item shape that will deliver wants mechanical properties and to watch the microstructure after heat treatment [7-8]. Carburizing similarly implied as case hardening is a heat treatment process that makes a surface which is impenetrable to wear, while keeping up toughness and nature of the inside. This treatment is



associated with low carbon steel parts in the wake of machining, and furthermore high composite steel bearing, gears, and distinctive portions [9-10]. Most carburizing is done by heating parts in either a pit warmer, or settled atmosphere radiator, and displaying carburizing gases at temperature. Gas carburizing considers exact control of both the system temperature and carburizing condition (carbon potential) [11]. The primary reason for the carburizing procedure is to get a hard and wear protection surface on machine parts by improvement of the surface layer with carbon to a fixation from 0.75 to 1.2 % and ensuing extinguishing. Steel which has been carburized and extinguished (case – solidified) has a higher weariness confine [12]. Low carbon steels, containing from 0.1 to 0.18 % carbon, might be subjected to carburizing. Steel with a higher carbon content (0.2 to 0.3 %c) might be utilized for vast segments Steel with expanded carbon content (0.25 to 0.35 %) has a more grounded center this empowers the profundity of the carburized case to be decreased along these lines streamlining resulting heat treatment [13-15]. It is notable that composites having high hardness tend to be weak and helpless to fast crack under load, and in this way an article or part made altogether from such an amalgam would not perform acceptably under affect or different sorts of quickly connected anxieties. This is especially valid in steels where high carbon substances are utilized keeping in mind the end goal to acquire high hardness. To overcome this inborn issue, the procedure of case solidifying has been created for steels [16]. In one process for case solidifying steel, the surface of an 'article or parts produced using a low-carbon steel is enhanced in carbon by warming the article or part in con thoughtfulness with a carburizing medium. Amid this carburizing treatment, carbon is caused to diffuse into the low-carbon steel to deliver an advanced layer, ordinarily between 0.005 inch and 0.100-inch profound relying on a definitive use for the article or part [17-18]. The carbon-enhanced layer, known as the case, more often than not contains around 0.6% to about 1.3% carbon, while the low-carbon divide remaining, known as the center, more often than not contains just around 0.05% to around 0.27% carbon. The real case solidifying is affected by cooling' the carburized article or part from a temperature at which the carburized case is totally or generously austenitic (austenitizing temperature) to a temperature at which the case changes to martensite [19-22]. The accomplishment of this austenitizing or solidifying temperature might be affected in a few ways. The article or part can be authorized at the austenitizing temperature or at a higher temperature and cooled specifically to cause change to martensite, or the article or part can be heated to an austenitizing temperature from room temperature after past carburizing or reining heat medications [23-25]. The impact of case solidifying is, hence, 'to create a hard, wear safe surface (case) which is likewise unavoidably fragile, furthermore, to consolidate this with a center which has great flexibility despite the fact that of lower hardness [26-28]. The significant part of eggshells is calcium carbonate,  $\text{CaCO}_3(\text{s})$  and it can be achieved volumetrically by utilizing a trademark response of carbonate mixes, in particular their response with acids. Calcium carbonate (limestone) is exceptionally insoluble in unadulterated water yet promptly responds in corrosive as indicated by the response underneath. Charcoal has turned out to be extremely attractive throughout the years and it is acknowledged by and large. Charcoal and also kindling have shaped a noteworthy piece of the sustainable power hotspot for creating territories of the world. Resellers evaluated that the market for charcoal can create up to \$1.8 billion dollars regarding vitality making its gross utilization higher than that of power [28-29]. Animal charcoal has additionally been utilized as carburization operator and it is gotten by scorching bones, meat and blood of creatures. The theme of testing mechanical materials has turned out to be such an imperative piece of designing, ending up similarly as vital as applying building strategies to enhance mechanical properties of metals and different materials utilized as a part of training [30]. As of late, more respect is given to the translation of the outcomes given by mechanical test regard to how they enhance execution in benefit and furthermore giving sensible understanding into the capacity of a material to play out the require work [31].

## 2. Materials and Method

The materials used in this research work were palm kernel shell and eggshell as shown in figure 1 which was first dried to remove the moisture content thereafter grinded, milled and sieved to pulverized fine smooth particles to increase the surface area of the agents and to increase the efficiency of the release of the carbon. Egg shell contains a good measure of calcium carbonate and it was used as an energizer. Palm Kernel Shell was recuperated as remaining waste in the extraction of the bit from the nut, after palm oil had been extracted from the monocarp of the oil palm organic product. Samples of hundred (100) pieces of ASTM A53 mild steel

with dimensional size of 100 x 30 mm each were used. The elemental composition of the sample steel material was checked using UV-VIZ spectrometric machine as shown in Table 3. Four sets of steel boxes were fabricated in the dimensions of 200 x 50 x 200 mm with two faces detachable and small extension for carrying the boxes at high temperature. Mixture of pulverized palm kernel and egg shell at a percentage ratio of 80 to 20 was engaged in the treatment. Muffle furnace of 2,500oC max was used for the carburization. An adequate precaution safety rule was followed in order to achieve high hardness with a high level of consistency and precision, while safeguarding the surrounding of the chamber condition. Prepared samples buried in pulverized carburizer and energizer at a mixed percentage ratio of 80 to 20 were put together in a muffle furnace for carburization process at different holding temperature and time of (HT- 60, 90, 120 and 180 minutes) and (CT- 950, 1000, 1050, 1100oC). This procedure was repeated severally with varying holding time and temperatures. The initial experiment begins from 950oC and goes up to 1100oC. It was ensured that the temperature range of the carburization process was below the melting point of the grade of steel chosen however over the austenizing temperature of the steel grade involved. The temperature blends were explained in the experimental design as shown in Table 1 and 2.

## 2.1 Experimental Design

Table 1- Case-hardening soaking time with temperatures

Holding Time / Number of minutes			
60 minutes/950oC	60 minutes/1000oC	60 minutes/1050oC	60 minutes/1100oC
90 minutes/950oC	90 minutes/1000oC	90 minutes/1050oC	90 minutes/1100oC
120 minutes/950oC	120 minutes/1000oC	120 minutes/1050oC	120 minutes/1100oC
180 minutes/950oC	180 minutes/1000oC	180 minutes/1050oC	180 minutes/1100oC

Table 2: Sample labels for the experiment

Temperature (°C)	Time (Mins)	Hardness	Test	Compositional Analysis
950	60	1B		1C
950	90	2B		2C
950	120	3B		3C
950	180	4B		4C
1000	60	5B		5C
1000	90	6B		6C
1050	60	7B		7C
1050	90	8B		8C
1100	60	9B		9C
1100	90	10B		10C
CONTROL	CONTNROL	CONTROLB		CONTROLC

Table 3: Compositional analysis

ELEMENTS	COMPOSITION (%)
C	0.25
Si	0.852
Mn	0.95
P	0.05
S	0.045

Cr	0.382
Ni	0.210
Mo	0.206
Al	0.022

**2.2 Core, Surface and Interface Hardness Test**

The hardness for core, interface and core was performed by utilizing an instrument called hardness tester, which applies distinctive burdens and appropriately arranged. The load was connected through an indenter relying upon the scale utilized. The hardness esteem was finished by estimating the extent of the mark left by the indenter in the wake of having impressed the load for a controlled time for the Vickers. The results for the hardness were shown in Tables 4, 5 and 6

**3. Experimental Results and Discussion.**

Table 4: Temperature and Time variation effects on surface hardness

Temperature	60 minutes	90 minutes	120 minutes	180 minutes	control
950	117.1	124.5	131.9	139.3	79.7
1000	139.15	139	119.24	99.47	79.7
1050	127.7	116.4	104.16	91.93	79.7
1100	108.1	118.5	105.56	92.63	79.7

Table 5: Temperature and Time variation effects on interface hardness

Temperature	60 minutes	90 minutes	120 minutes	180 minutes	Control
950	125.4	127.2	129	130.8	132.5
1000	127.35	123.9	119.24	99.5	132.5
1050	120.95	118.0	114.16	100.9	132.5
1100	127.4	146.0	125.6	102.6	132.5

Table 6: Temperature and time variation effects on core hardness

Temperature	60 minutes	90 minutes	120 minutes	180 minutes	control
950	128.1	123.76	119.43	115.1	124.5
1000	120.3	125.5	125.2	124.9	124.5
1050	122.2	118.9	120.77	122.64	124.5
1100	147.7	133.5	130.5	127.5	124.5

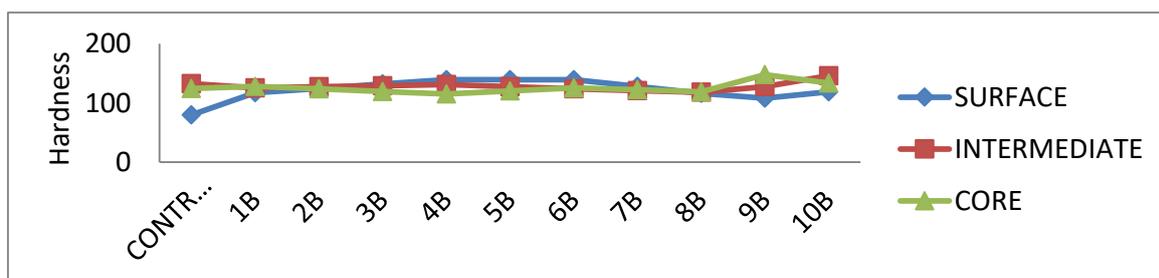


Figure 1: Hardness variation behaviour on case-hardened samples.

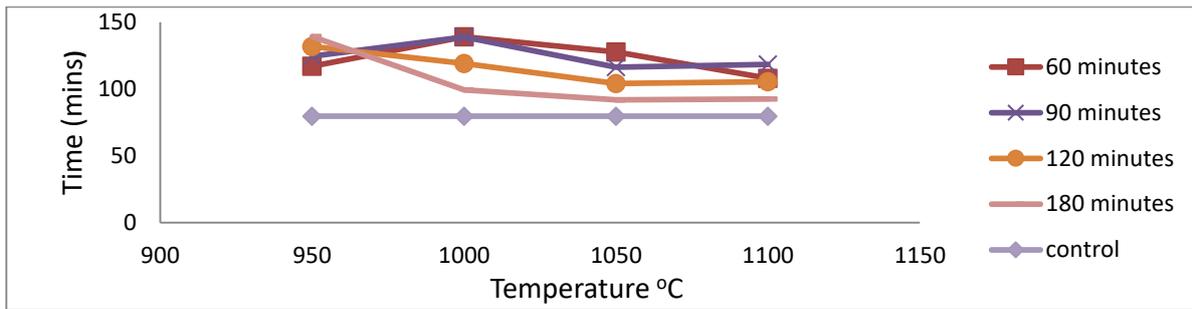


Figure 2: Effects of time and temperature variance on surface hardness.

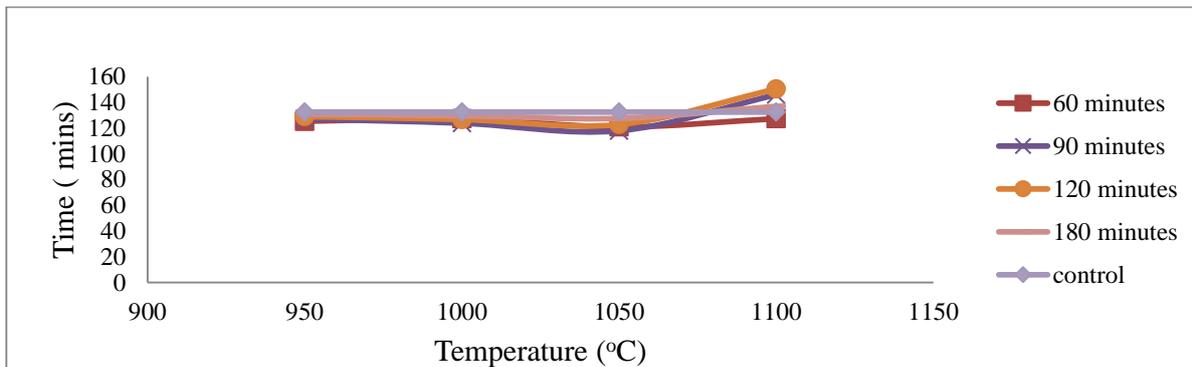


Figure 3: Effects of time and temperature variance on interface hardness

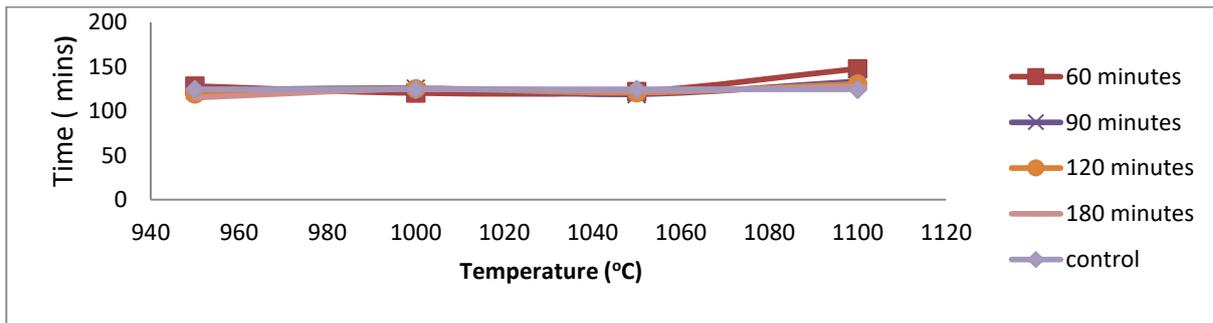


Figure 4: Effects of time and temperature variance on core hardness.

### 3.1 Discussion

The behaviour of the results shown in Figure 1 provides us with the knowledge that the more holding time applied to the case hardening at different temperature, the more carbon will be infused into the surface of the steel. Considering the hardness variation behaviour on case-hardened samples in Figure 2 with surface hardness of 139.4 HV at holding temperature 980oC and time 180 minutes gave best increase of 43% over the control of 79.7 HV. Checking through Figures 3 and 4, hardness at interface and core were 146 HV and 147 HV with percentages increase of 9 and 15.3 achieved. The best hardness test result shown above was due to the application of eggshell as an energizer which improved the mechanical properties of the carburized steel. The first of which was the surface hardness that increased generally at every sample test because of the high

penetration of infused carbon into the surface of the material and formed a deeper case in agreement with Afolalu et al., (2015). Also, from the graphs it can be seen that as the holding time increases, there was an increase in hardness but some cases, increase occurs at a diminishing rate which was in relation to what was postulated by Aramide (2009).

#### 4. Conclusion

This project focused on ASTM A53 mild steel and with the positive results obtained, similar method can be engaged on other grades of steel and recycling of wastes with element of carbon should be encouraged. The findings in this study also confirmed that locally source materials with the required chemical composition can be used to replace foreign chemicals intended for the same purpose.

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