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# Microstructure, Mechanical & Wet Wear Properties of Cast Iron in Normal Ascast Condition and Nitrotec Treated Condition at 570ºC and 630ºC

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Grey iron, or gray iron, is a most commonly used cast iron that contains carbon in the form of graphite flakes. It is named after the grey color of the fracture it forms, which is due to the presence of graphite. It is the most common cast iron and the most widely used cast material. In order to improve the properties of grey cast iron, it can be heat treated to bring about the changes in the microstructure and the properties. Nitrotec is a worldwide patented Surface Engineering Process for the treatment of steels and cast irons carried out in the temperature range of 570□C and 630□C. using a gaseous nitrogen bearing atmosphere. The treatments develop iron nitride surface compound layers between 5 and 50mm thick, supported by a nitrogen rich diffusion zone in the substrate. Substantial information relating to the structure and mechanical properties of Grey cast iron is available. Also substantial information is available relating to the Nitrotec treatment on steels and cast iron. However, there is a scope for conducting studies to evaluate microstructure examination, mechanical properties and wear studies on the Nitrotec treated grey cast iron. There is no extensive data available on Nitrotec treated Grey cast iron pertaining to microstructure examination, mechanical properties and wear studies.

**Keywords:** Cast iron; Microstructure; Mechanical properties; Wear; Nitrotec treatment.

## 1. Introduction

Cast irons make up a family of ferrous metals with a wide range of mechanical properties. They are produced by being cast into shape as opposed to being formed. Cast irons are alloys of iron and carbon where the carbon content is more than 2% and 1 to 3% of Silicon. Its versatility arises due to the wide ranging physical properties which are possible due to alloy addition and various heat-treatment procedures.Grey iron, or grey iron, is a most commonly used cast iron that contains carbon in the form of graphite flakes [1]. It is named after the grey color of the fracture it forms, which is due to the presence of graphite. It is the most common cast iron and the most widely used cast material based on weight. The typical composition of grey cast iron is total Carbon: 2.5 to 4.0 %, Silicon: 1.0 to 3.0 %, Manganese: 0.2 to 1.0%, Sulphur: 0.02 to 0.25 %, Phosphorus: 0.002 to 1.0 %. Grey iron is the most versatile of all foundry metals. The high carbon content is responsible for ease of melting and casting in the foundry and for ease of machining in subsequent manufacturing [2]. The low degree or absence of shrinkage and high fluidity provide maximum freedom of design for the engineer. In order to improve the properties of grey cast iron, it can be heat treated to bring about the changes in the microstructure and the properties. Nitrotec is a worldwide patented Surface Engineering Process

for the treatment of steels and cast irons carried out in the temperature range of 550-740 C using a gaseous nitrogen bearing atmosphere. The treatments develop ironnitride surface compound layers between 5 and 50μm thick, supported by a nitrogen rich diffusion zone in the substrate [3]. Beneficial Properties using the Nitrotec are wear resistance, bearing characteristics, indentation resistance, corrosion resistance, strengthening dimensional control, aesthetic finish etc. Nitrotec is a worldwide patented Surface Engineering Process for the treatment of steels and cast irons carried out in the temperature range of 550-740 C using a gaseous nitrogen bearing atmosphere. The treatments develop iron nitride surface compound layers between 5 and 50μm thick, supported by a nitrogen rich diffusion zone in the substrate [4]. An innovative oxidation technique, combined with specially formulated aqueous quenchant and organic sealant are incorporated depending on the engineering requirements of a specific application. The Nitrotec process converts the surface of the cast iron specimens into a black, corrosion resistant iron oxide (Fe3 O4) layer. Beneath this layer is the epsilon iron nitride (Fe3 N) layer.

The present study is focused on the Microstructure, mechanical & wet wear properties of cast iron in normal ascast condition and Nitrotec treated condition at 570°C and 630°C.

## 2. Methodology

### 2.1 Microstructure Examination

The microstructure of any engineering material is one of the most important aspect as it is related to its composition, properties, processing history and performance.

Stepsinvolved in the preparation of specimen for microstructure examination are described below.

❖ Sectioning: The micro examination sample needs were sectioned using suitable cutter. The burrs and sharp edges were removed by rough grinding i.e., by using an abrasive belt grinder.

❖ Grinding: the grinding operation was performed in successive steps using silicon carbide, abrasive papers of 100, 220, and 400 grits [5]. Fine grinding was done using 1500, 2500 and 3000 grit silicon carbide papers. These papers were fixed to a rotating wheel with running water to flush away any loose abrasive particles.

❖ Polishing: Two types of polishing were performed. Initially rough polishing was performed by using distilled water on a blazed cloth fixed to the rotating wheel. After the rough polishing the fine polishing was performed by hand on micro cloth using fine polishing compound (diamond paste). The samples were then washed in running water and dried [6].

❖ Etching: Samples were etched using 3% Nital consisting of 96-98 ml of ethanol and 2-4 ml concentrated nitric acid. The structure examination was done after washing and drying thoroughly. Optical microscope was used for microstructure examination [7].

Figure 1 and Figure 2 shows the details of the optical microscope and double disc polishing machine and the double disc polishing were used in the present investigation.

Fig. 1 Optical microscope


Fig. 2 double disc polishing machine

2.2 Mechanical properties

Specimen for mechanical properties evaluation was machined from the ascast castings. Mechanical properties such as ultimate tensile strength, percentage elongation and hardness measurement (Vicker's Hardness) were carried out on the ascast grey cast iron and grey cast iron subjected to Nitrotec treatment.

2.2.1 Tensile Test

Bench Tensometer was used in the present investigation [8]. The standard tensile specimens were machined from castings. The dimension details of the specimen are shown in Figure 3. Figure 4 shows the details of the tensometer used in the present investigation.

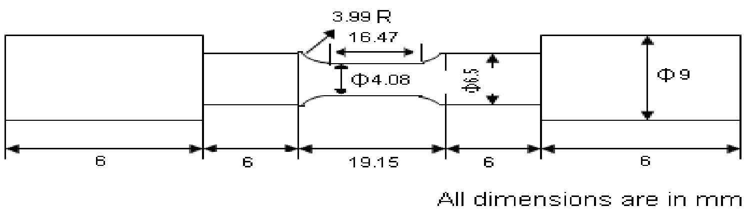



Fig. 3. Dimensional details of the tensile specimen


Fig. 4. Bench Type Tensometer

2.2.2 Hardness Measurements

Vicker’s hardness measurements were carried out on ascast and Nitrotec heat treated specimen. Diameter 10mm X 10mm height specimen was used for this purpose [9]. Standard procedure was employed. An average of 4 hardness measurements at different locations across the cross section of the specimen has been considered for the analysis. Figure 5 shows the details of the Vicker’s hardness tester and the specimen details for hardness tests.

Fig. 5. Vickers Hardness Tester

- Before the test area of the specimen was cleaned and made even and polished. The lower sides of the specimen were also made even and cleaned, so that the specimen was well seated on the support [10].

- Load of 100 gms was selected and the specimen was placed on the anvil so that its surface was normal to the direction of the applied load.
- Hand wheel was turned slowly so that the specimen got focused on to the front screen sharply, till the gap between tip of diamond indenter and the top of the specimen was between 0.2 to 0.25 mm.
- The anvil was then raised by means of rotating the hand wheel until the specimen just makes contact with the indenter. Dwell timer was adjusted for 25 sec [11].
- Load was applied by means of hand lever for the prescribed time. The load was released and indentation was focused on to a graduated ground glass screen.
- The magnified diagonal length of the indentation was measured by means of the vernier mechanism provided in the screen and then finally Vickers hardness number was calculated.
- An average of 4 measurements at different locations across the cross sectional area was taken as the hardness of the specimen [12].
- The above procedure was repeated for other conditions also.

Vickers Hardness number was calculated using the following formula:

$HV = 1.854 * P/d^2$

Where: P = the test load applied in Kgs

d = Average diagonal length of the impression in mm.

2.3 Wet wear abrasive test

Wear studies were carried out in wet condition using a wet wear abrasive machine. Weight loss method was employed to assess the wear of the specimen [13]. The detailed procedure of wet wear test is as follow.

Figure 6 shows the details of the wet abrasive wear testing machine used in the present investigation.

Fig. 6. Wet abrasive wear testing machine

Test procedure:

- The test specimens were weighed prior to the test.

- The disc was fully cleaned and test specimens were fixed in position.
- Silica sand water slurry in the ratio of 2:1 was kept inside the drum in such a way that all the specimen dipped into it [14].
- A thin cover plate was put above the disc.
- The motor was switched on.
- The test was run for 24 hours at intervals of three hours. At the end of every 3 hours of testing, the unit was switched off.
- The specimen was taken out of the specimen holder, cleaned thoroughly, dried and weighed in an electronic balance. Loss in weight of the specimen before the test and after conducting the test (weight loss method) has been employed to assess the wear of the specimen [15].
- The above test was conducted for different pH values of the solution namely pH equal to 4 and 6.
- The graph of weight loss verses test interval duration and pH verses test interval was drawn.

## 3. Results and Discussions

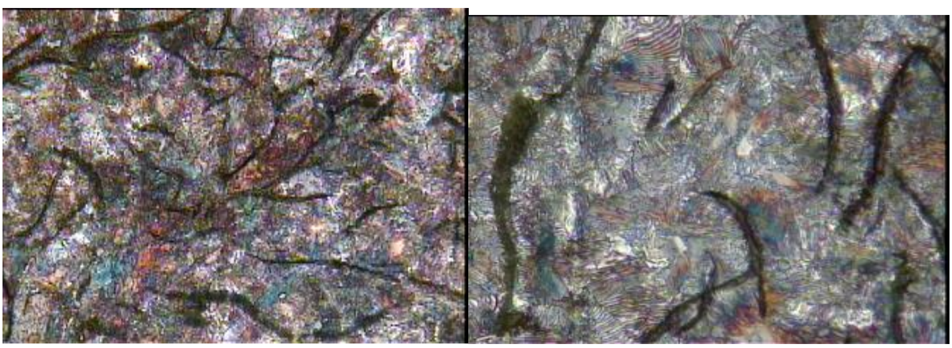
### 3.1 Microstructure examination

The details of the microstructure examination carried out on gret cast iron for Ascast and Nitrotec treated specimens are presented below:

The specimens for microstructure analysis were prepared by polishing and etching by using 2% nital (98% ethanol and 2% conc nitric acis) and viewed under optical microscope [16].

#### 3.1.1 Ascast condition

It may be seen from the Figure 7 that the microstructure of grey cast iron.



(a) (b)

Fig. 7. Micrograph of Grey cast iron Magnification: (a) 100X (b) 200X

The study of the micrograph indicates the graphite flakes distributed in pearlite matrix.

3.1.2 Nitrotec Treated condition

Figure 8 shows the micrograph of Grey cast iron with Nitrotec treatment Magnification of 100X.

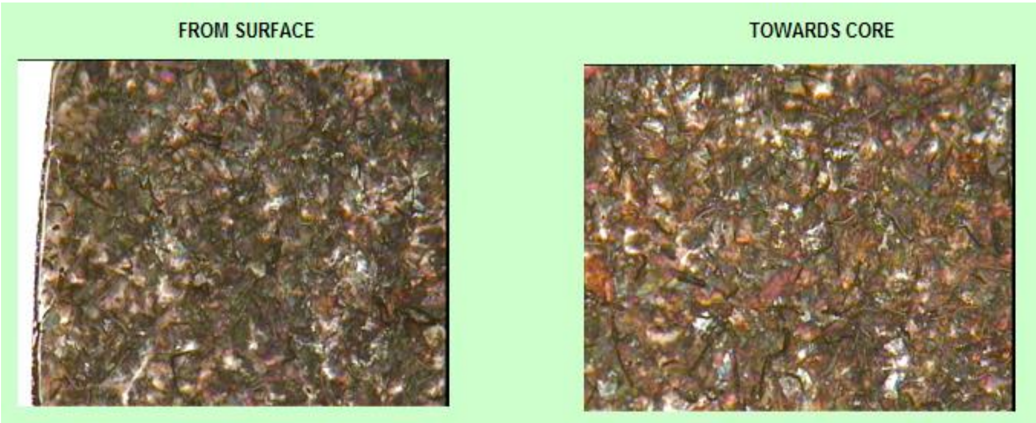



Fig. 8. Micrograph of Grey cast iron with Nitrotec treatment Magnification of 100X

3.2 Hardness Values

Vickers hardness measurements were carried on the ascast and Nitrotec treated gery cast iron specimens. Hardness measurements were carried out at 3 different locations across the cross section and average value of the hardness has been considered for the analysis [17].

The variation of the hardness values for the ascast grey cast iron and Nitrotec treated grey cast iron, treated at 570º C and 630º C are shown in Figure 9.

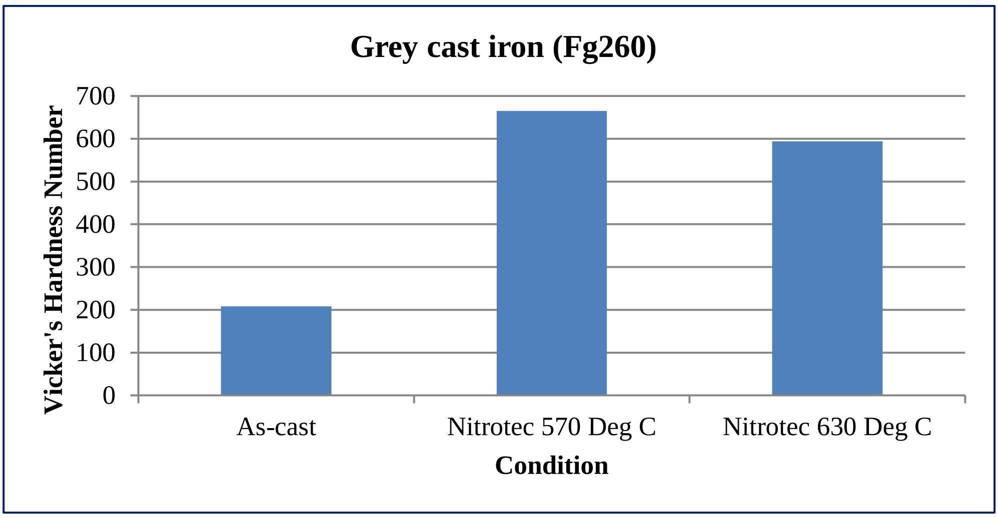



Fig. 9. Variation of hardness values of ascast grey cast iron and Nitrotec treated

Grey cast iron

It is observed from the figure that the hardness value of the ascast specimen is less compared with the Nitrotec treated specimen. A hardness value of 208 VHN is noticed for the ascast condition, whereas 665 VHN and 594 VHN are noticed for the Nitrotec treated specimen, treated for $570^0$ C and $630^0$C respectively [18]. This indicates that Nitrotec treatment has a considerable effect on the hardness values of the specimen. Higher hardness value of 665 VHN is noticed for the Nitrotec treated specimen at $570^0$ C compared with 594 VHN obtained for the specimen treated at $630^0$C. This indicates that lower Nitrotec temperature results in increased hardness values. Higher hardness values are noticed in the Nitrotec treated specimen, treated at 570º C [19].

3.3 Ultimate Tensile Strength values

The variation of the ultimate tensile strength values for ascast grey cast iron and grey cast iron subjected to Nitrotec treatment at 570º C and 630º C is shown in Figure 10.

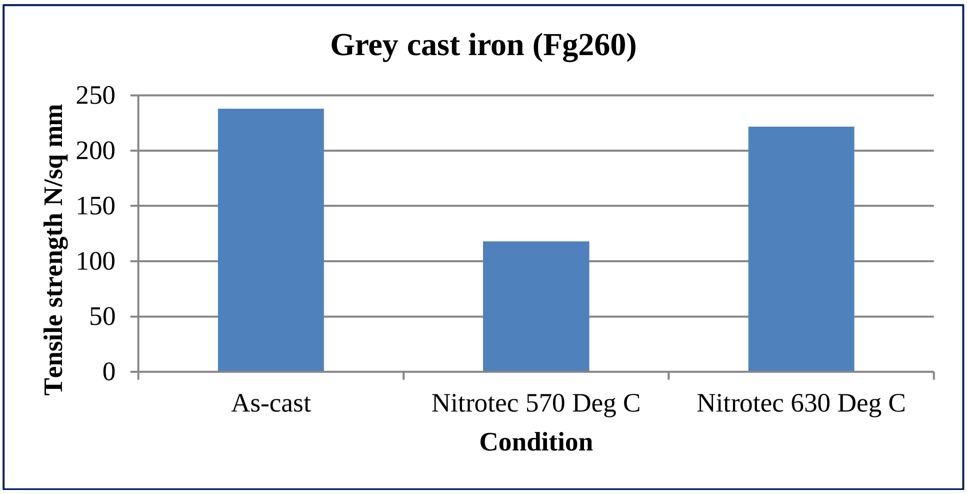



Fig. 10. Variation of UTS values of ascast grey cast iron and Nitrotec treated grey cast iron.

It can be observed from the figure that the ultimate tensile strength of the ascast specimen is higher than the Nitrotec treated specimen. Higher ultimate tensile strength values 237.9 $N/mm^2$ are noticed in the ascast specimen whereas an ultimate tensile strength value of 117.9 $N/mm^2$ and 221.6 $N/mm^2$ are observed with the Nitrotec treated specimen [20]. This may be due to the formation of the oxide layer ($Fe_3O_4$) upon subjecting the specimens to Nitrotec treatment which resists the applied load. A marginal increase in ultimate tensile strength values is seen with increase in Nitrotec temperature from 570º C to 630º C [21].

3.4 Wet wear abrasive tests

The wet wear abrasive test results carried out on ascast grey cast iron specimen (conforming to FG 260 grade) and Nitrotec treated for two different temperatures ($570^0$ C and $630^0$C for 180 minutes duration) are presented under the following Table 1.

Table 1. Wet wear abrasive test results carried out on ascast grey cast iron specimen and Nitrotec treated for two different temperatures

| pH investigated | Total duration investigated |
|---|---|
| Neutral | 24 hrs. |
| 4 | 24 hrs. |
| 6 | 24 hrs. |

The discussion has been carried out for a different pH values and duration of each interval 3 hrs for total 24 hrs test period [22].

Figures 11, Figure 12 and Figure 13 shows the variation of the weight loss with time for the ascast specimen and Nitrotec treated specimen.

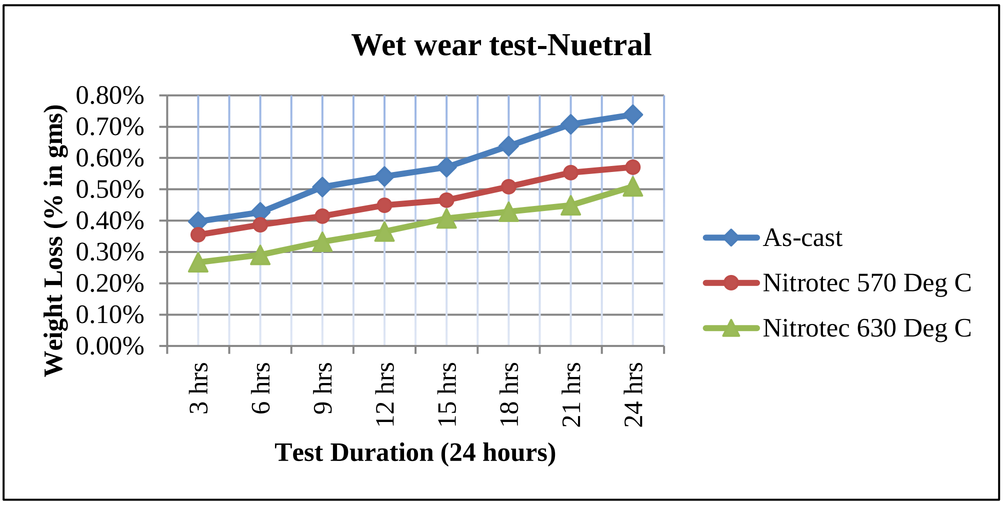



Fig. 11. Variation of weight loss (%) with time for the ascast specimen and Nitrotec treated specimen.

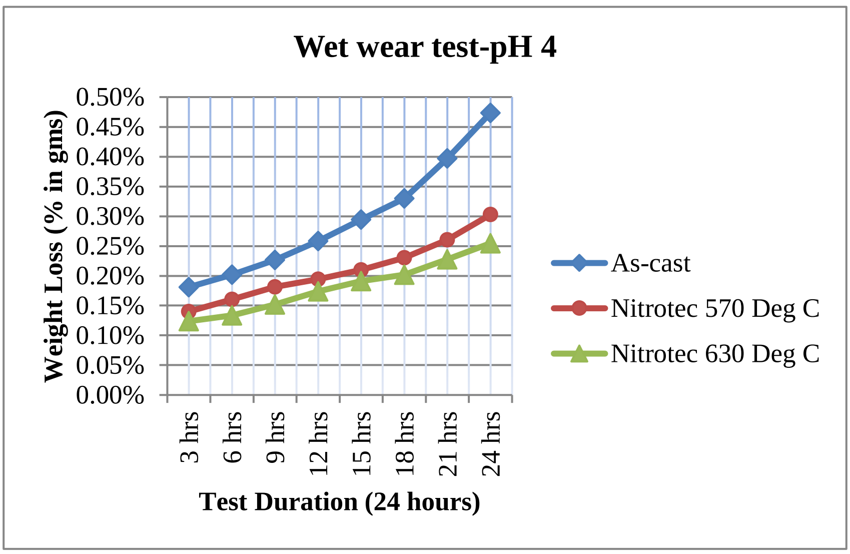



Fig. 12. Variation of weight loss (%) with time for the ascast specimen and Nitrotec treated

specimen.

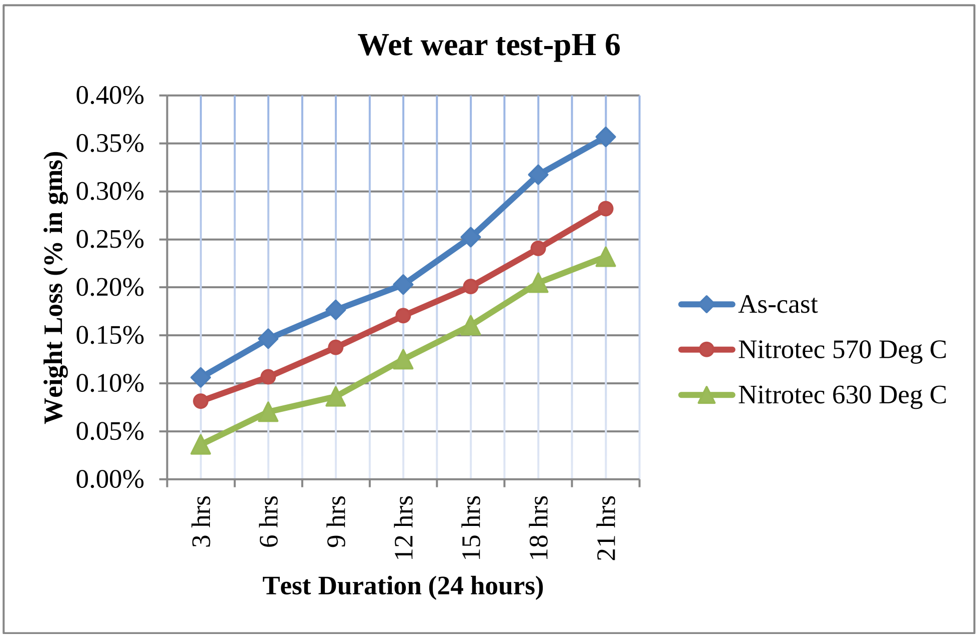



Fig. 13. Variation of weight loss (%) with time for the ascast specimen and Nitrotec treated specimen.

It can be observed from these figures that the weight loss increases steadily with increase in the time of testing.

## 4. Conclusions

The following conclusions are drawn from the present study.

- The study of the micrograph indicates the graphite flakes distributed in pearlite matrix.
- Severe wear is noticed in the ascast condition - whereas less wear is seen with Nitrotec treated specimen.
- Nitrotec treated specimens treated at 570º C exhibit lower weight loss compared with the ones treated at 630ºC. This may be due to the higher hardness values obtained for low Nitrotec temperature treated ones.
- The weight loss increases steadily with increase in the time of testing. Hence the study indicates that Nitrotec treatment has a significant effect on the wear properties of grey cast iron.
- It can be observed from the figure that the ultimate tensile strength of the ascast specimen is higher than the Nitrotec treated specimen. A marginal increase in ultimate tensile strength values is seen with increase in Nitrotec temperature from 570º C to 630º C.

- It is observed from the figure that the hardness value of the ascast specimen is less compared with the Nitrotec treated specimen. A hardness value of 208 VHN is noticed for the ascast condition, whereas 665 VHN and 594 VHN are noticed for the Nitrotec treated specimen, treated for $570^0$ C and $630^0$C respectively.

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