Effect of Austenitic Nitrocarburizing of mild steel under varying cooling rate and ageing conditions

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Abstract **- Nitrocarburizing is a thermochemical diffusion process involving the simultaneous addition of nitrogen and carbon to the surface of ferrous materials. The properties like better surface hardness, high wear-resistance, excellent fatigue strength, improved corrosion resistance; zero to Minimal distortion can be attained by Austenitic Nitrocarburizing (ANC). The reason is a nitrogen austenite layer is developed as substrate between the compound layer and the diffusion layer. The mild steel sample is treated on ANC under Fluidised Bed Furnace in various cooling rate and ageing at different temperature conditions. This effect results in variation in the microstructure of the sample after processing and in the micro hardness of the material. It has been found that the hardness of the sample on Austenitic Nitrocarburizing is greater than that of the sample on Ferritic Nitrocarburizing. Therefore it is necessary to know at what condition the hardness will be good.**

I. Introduction

Nitrocarburising is a thermochemical diffusion process involving the simultaneous addition of nitrogen and carbon to the surface of ferrous materials. The process is classified into two groups namely

1. Ferritic Nitrocarburising (FNC)
2. Austenitic Nitrocarburising (ANC)

Ferritic Nitrocarburising (FNC)

This process is generally done at temperatures below 580° C (1076° F) involves the addition of nitrogen and carbon. It is also called short nitriding process. It is done in an atmosphere containing NH3and a carbon donor such as LPG, CO2 or Propane. The ferrous material after this process need not be quenched if surface hardness is the only consideration. However if the steel after the process is quenched in oil or water, nitrogen is retained in solution in the diffusion zone which contribute for improved fatigue life.

Austenitic Nitrocarburising (ANC)

This is conducted at temperatures between 590°C (1094 F) to 720°C (1328 F). In this temperature range, the ternary alloy Fe-C-N forms austenite and hence the name austenitic nitrocarburizing. The process atmosphere generally consists of N2, NH3 and a carbon donor like natural gas or CO2 or LPG etc. It produces a surface compound layer of epsilon iron nitride and a diffusion zone that contains transformed martensite. By processing at higher temperatures than a Ferritic Nitrocarburizing (FNC) process, a portion of the diffusion zone under the compound layer is austenitized as it is stabilized by additional nitrogen content and transforms to martensite upon quenching. This additional hardened diffusion zone below the compound layer creates additional case depth over a ferritic nitrocarburized surface.

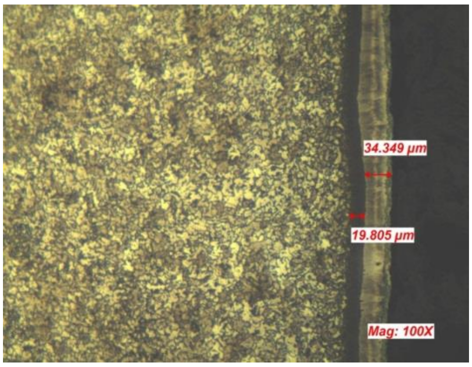
The main aim of the project is to study the Effect of Austenitic Nitrocarburizing of mild Steel sample under various cooling rate and ageing at different temperature conditions. The effect results in variation in the microstructure after processing and thus in the microhardness of the material.

II. Experimental Procedure

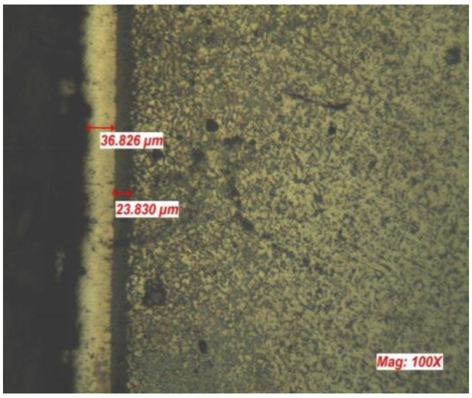
The component of mild steel (rod) is sampled into pieces. Initially a green sample/unprocessed sample is moulded and polished for observing the material's native microstructure. Then the samples are placed inside the fluidised bed furnace whose temperature is maintained at **660°C.** The samples are allowed to undergo austenitic nitrocarburizing process for a period of 2 hours of soaking time. The rate of various compounds input into the furnace to enhance the process of austenitic nitrocarburizing are Nitrogen **N_2 – 0.6 m^3/hr, Ammonia NH_3 – 0.36 m^3/hr, LPG – 0.12 m^3/hr** which comprises a total rate of 1.08 m^3/hr. After 2 hours of soaking into the furnace the samples are taken out in a safe manner and are quenched or cooled in three different rates for a same period of 10 minutes.

A set of samples are quenched in oil which represents fast cooling rate, another set of samples are placed in another fluidised bed furnace of temperature 450^{o}C which represent slow cooling rate and another set of samples are let to cool in air which represents moderate cooling rate. A single sample quenched in each quenchants is moulded and polished for observing the microstructure of the respective samples. Each sample quenched in all the three set of quenchants are taken and are made to undergo ageing in four different temperature conditions for a period of 1 hour of soaking time. Each samples quenched in each quenchant is taken and placed into four different furnaces of temperature 200^{o}C, 350^{o}C, 450^{o}C and 550^{o}C respectively. After undergoing ageing the samples are taken out in a safe manner and each sample are moulded and polished. Then after that observing the microstructure of the respective samples.

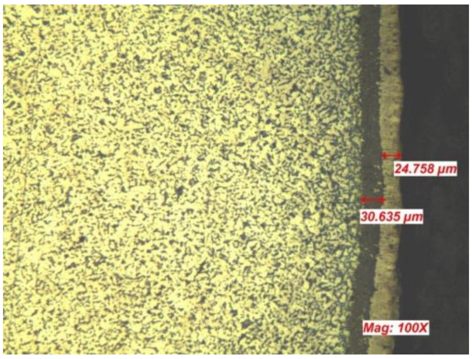
Microstructural Observation



(a)



(b)



(c)

Figure **(a)** Air cooled Aged at 350°C showing converted Bainite layer, **(b)** Oil quenched Aged at 350°C showing converted Bainite layer but γ^{I} is predominant, **(c)** Furnace cooled without ageing condition showing fully converted Bainite layer.

The microhardness of each sample is been found with the help of **Vicker's micro hardness tester** and the values are tabulated and a pictorial graph is been plot in order to observe and conclude the variation in the properties of the sample in accordance to the microhardness.

III. Results and Discussion

Figure 2 shows that maximum hardness is attained for the sample aged at 350°C (724 HRC). At first the epsilon Nitride is formed and at 200°C ageing conditions the Bainite and austenite deformation takes place. Then at 350°C, the austenite is fully converted into Bainite. Then at 450°C some pores are occur and at 550°C the carbide particles are formed i.e., the specimen said to be over aged condition.

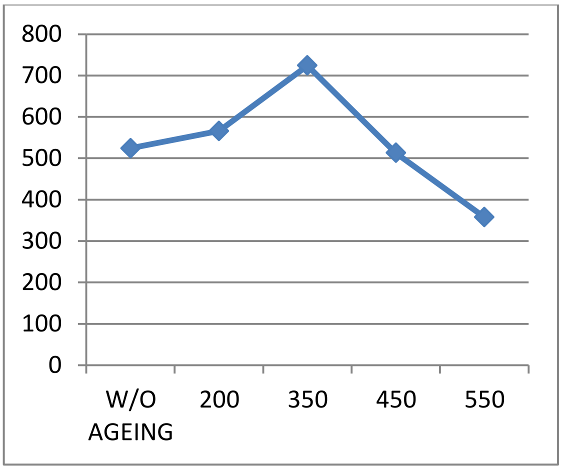


Figure 2

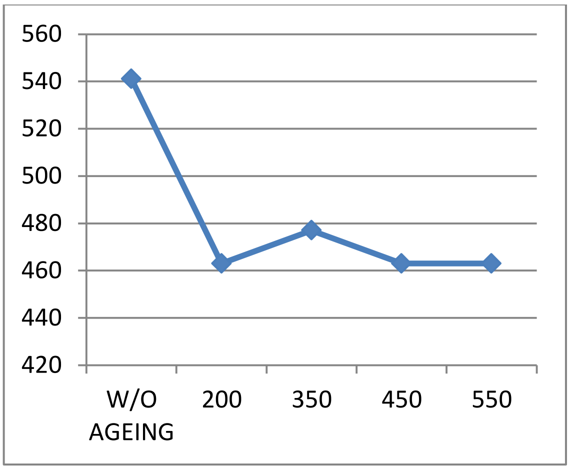


Figure 3

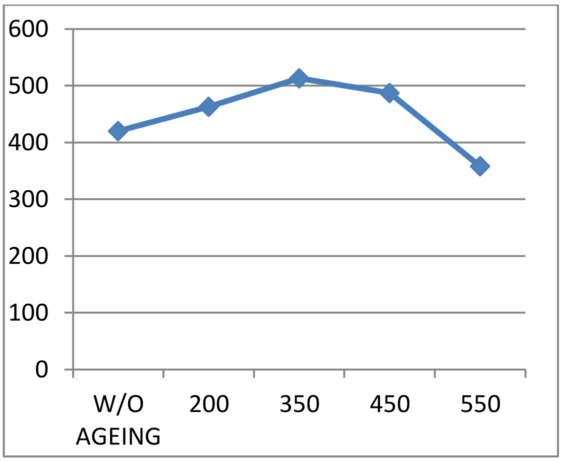


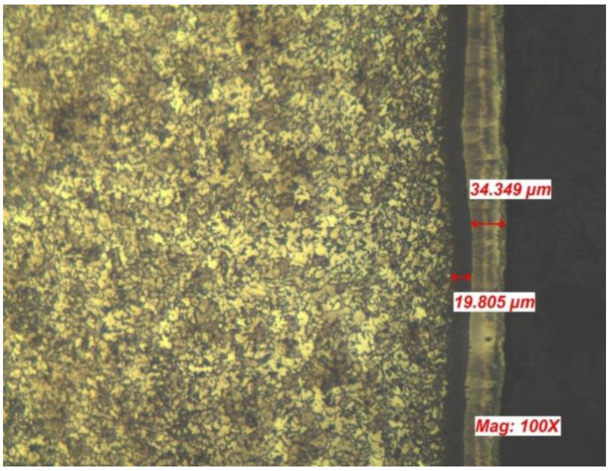
Figure 4

Figure 3 shows that maximum hardness is attained in without aged condition (541 HRC). At first the Bainite layer is formed with insignificant porosity but in the other conditions the Bainite is present along with the substrate austenite.

Figure 4 shows that maximum hardness is attained at 350°C (513 HRC). At first the epsilon Nitride is formed and at 200°C ageing conditions the substrate austenite remains. At 350°C the substrate austenite is fully converted to Bainite and gives maximum hardness value. For other ageing conditions the carbide particles are formed and also the etching characteristics are different.

CONCLUSION

In Furnace cooled sample the microharness seems to be uneven and the microhardness remains almost constant after certain temperature which may due to the influence of the substrate properties. In Air cooled and Oil quenched sample the microhardness of the material seems to be peak at 350^{o}C which may due to the influence of the converted Bainite.



Hence we conclude that on ageing at 4 various conditions, the Austenite substrate gets completely converted to Bainite at 350^{o}C. After 350^{o}C the microharness of the material drops which may be due to the precipitation of the carbide present in the layer. Hence we decide that after 350^{o}C the process leads to over ageing and loses its hardness value.

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