Comparison of Effect of Ferritic Nitrocarburising on En-19,En-24 and En-37 Steels.

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Abstract. Nitrocarburizing is one of the prominent surface treatment methods for steels. The effects of ferritic nitro carburizing on En-19, En-24 and En-37 steels are compared. Microstructural investigations of FNC treated samples are carried out. Micro hardness profiles of FNC treated steels are drawn. Further wear investigations are carried out. It is observed that FNC treated En-19 steel has more wear resistance in comparison to En-24 and En-37 steels.

Key words. FNC treatment, wear resistance, micro hardness.

1 Introduction:

Many industrial applications demand a material with superior surface hardness and wear resistance. At the same time the material demands relatively tough core to enable it to have high shock resistance. Conventional heat treatment techniques reveal that a material with such combination of hard and wear resistant surface with tough core can be produced either by thermal treatment or by thermo- chemical treatment[1-3]. Thermal methods include flame hardening, induction hardening etc. whereas thermos- chemical treatments include nitriding, carburizing etc. The inherent drawback of thermal treatments is their inability to maintain control over the hard layer formed on the surface of material. Thermo- chemical methods like carburizing, nitriding and carbo nitriding can be employed for the purpose but their operating temperature is above the lower critical temperature of steel and subsequent quenching of the material in the process of bringing to room temperature may develop problems like cracking and distortion. In cases of stringent design considerations even slight distortion may not be tolerable. In such cases nitriding, whose operating temperature is lower than lower critical temperature, seems to be an alternative. But the basic problem with nitriding is the need for removal of hard and brittle white surface layer. It may be difficult to accurately grind this white layer, however the best precautions are taken. Further above treatments may work well for high carbon steels but there is a necessity to arrive at heat treatment process that can produce hard and wear resistant case with tough core for low carbon alloy steels. Literature [4]

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reveals that low carbon alloy steels can be subjected to nitrocarburizing. There are two types of nitrocarburizing-namely ferritic nitrocarburizing and austenitic nitrocarburizing. Austenitic nitro carburizing is carried out in the austenitic range at temperatures between Fe-N and Fe-C eutectoid temperatures i.e. 590^0C to 720^0C whereas ferritic nitro carburizing is taken up bellow the Fe-N eutectoid temperature i.e. 590^0C [5]. In contrast to carbonitriding nitro ferritic nitrocarburizing is carried out at temperatures lower than sub critical temperatures, which enables the steel parts to be surface hardened without much problem of cracking. Nitro carburizing confers unique combination of properties to steel parts with least risk of quench cracking. A variety of furnaces are available for performing nitro carburizing [6] .Fluidized bed furnace is one such furnace. The superiority of fluidized bed furnace over conventional furnaces is its ability to give good heat transfer to yield high degree of thermal uniformity. In the present work ferritic nitro carburizing is performed on low carbon alloy steels and the nitrocarburizing medium is in gaseous state.
The response of a low carbon alloy steel to ferritic nitro carburizing treatment depends on its percentage of carbon and type & percentage of alloying elements in alloy steel. Hence this work concentrated on comparing the effect of ferritic nitro carburizing on various structural steels.

2 Objective:

To compare the effect of ferritic nitrocarburizing on various structural steels like En-37, En-24 and En-19.

3 Materials:

Three structural steels are chosen. Chemical analysis of En-19, En-24 and En-37 steels is given in Table -1

Table-1(a) Chemical composition of En-19 Steel:

Element	**C**	**Mn**	**Mo**	**Cr**	**Si**
%	0.36	0.6	0.3	1.0	0.2

Table-1(b) Chemical composition of En-24 Steel:

Element	**C**	**Mn**	**Ni**	**Cr**	**Mo**	**Si**
%	0.35	0.5	1.5	0.9	0.2	0.2

Table-1(c) Chemical composition of En-37 Steel:

Element	**C**	**Si**	**P**	**Cu**	**S**
%	0.26	0.4	0.04	0.2	0.05

4 Experimental procedure

Samples of En-37, En-24 and En-19 steels are subjected to ferritic nitrocarburizing. A fluidized bed furnace is used for this purpose. In nitrocarburizing the metallic character of the surface is modified into nonmetallic layer through diffusion of carbon or nitrogen or both simultaneously. Gaseous ferritic nitrocarburizing is developed from gaseous nitriding process. Earlier investigations[2,7] observed that mere 12 to 20 hours of gaseous nitrocarburizing treatment is sufficient for achieving the desired properties as against the time requirement of 60 hours while classical gaseous nitriding is employed. The extent of surface layer and the constituents of surface layer greatly relies upon the furnace atmosphere and the degree of attainment of equilibrium during the process. It is reported that mere presence of oxygen boosts up the reaction kinetics.

Fluidized bed furnace of 150x300mm size with chrome-alumel thermo- couple is used. The fluidized bed furnace is given in fig 1. Fluidized bed furnace is maintained at temperature of 575^0 C and the temperature was maintained within plus or minus 3^0 C. The total flow of gases at 575^0 C is fixed i.e. 1.28 m^3/hr[6]. The ratio of LPG to ammonia is 1:4.

Furnace atmosphere composition is given below.

Content of Ammonia gas – 0.512 m^3/hr.; Content of Air—0.64 m^3/hr.; LPG content -0.128 m^3/hr.

The total flow of gases amounts to 1.28 m^3/hr.

Employing Ammonia in the furnace atmosphere not only acts as the lead source of nitrogen but also catalytically disassociate on ferrous component at temperature less than Fe-N eutectoid temperature. Samples of En-37, En-24 and En-19 steels of 25mm diameter and 25mm height are subjected to ferritic nitro carburizing one after the other in the above atmosphere for cycle time of two hours for each sample .

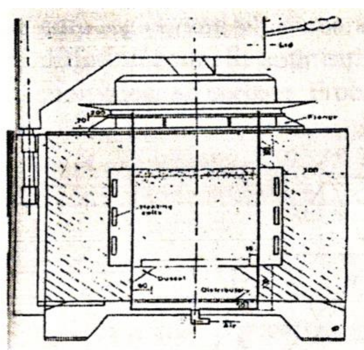

Fig. 1. Fluidized bed furnace

5 Microstructural investigations:

Microstructural studies are carried out for each of the above samples after ferritic nitro carburizing. The microstructure of FNC treated En-19, En-24 and En-37 steel samples are given in fig -2.

It can be observed that a distinct non- metallic compound layer is seen at the surface for all the samples. However, the thickness of the compound layer depends on the nature of steel and the composition of alloy. Fig-2 reveals that the thickness of compound layer ranges from 20 to 50 microns. En-19 steel registers a compound layer of 50 microns thickness whereas En-24 registers sightly thin layer of around 30 microns thickness and En-37 steel registers compound layer of least thickness around 20 microns. However compound layer formed in En-19 steel has higher hardness in comparison to En-24and En-37 steels. Probably the type of alloying elements -Cr, Mo and Ni and percentage of carbon are contributing to formation of compound layer which may contain epsilon carbonitride. Among all the three steels considered, En-37 steel registers compound layer of least thickness and hardness. Least percentage of carbon and carbide forming elements in this steel can be attributed to thin compound layer of inferior hardness.

For all the samples, a clear-cut distinction is observed between the layer immediately below the compound layer and the core region. It indicates that in between the surface layer-compound layer and core region there exists a distinct zone -known as diffusion zone. This diffusion zone may occur at a distance of 30 to 300 microns from the surface. Diffusion zone properties solely depend on alloy composition. During FNC treatment only nitrogen gets diffused in to sub surface layer. This diffused nitrogen may form iron nitride needles in diffusion zone which may introduce compressive stresses in diffusion zone leading to improvement in fatigue properties. Similar observations are reported previously [7,8]

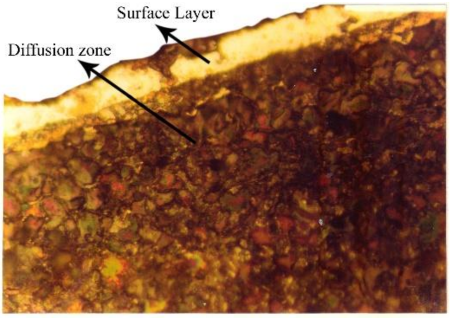

Fig-2(a) Microstructure of FNC treated En-19 steel.

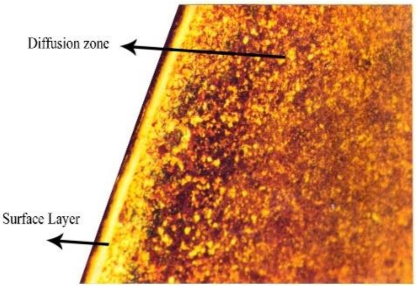

Fig-2(b) Microstructure of FNC treated En-24 steel.

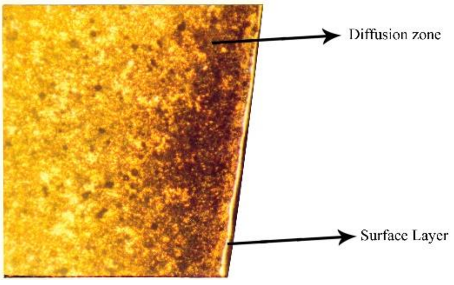

Fig-2(c) Microstructure of FNC treated En-37 steel.:

6 Microhardness Profile:

Both treated and FNC treated samples are tested for micro hardness using Vickers microhardness tester. Microhardness profiles are given in fig 3. From fig-3, it can be inferred that higher hardness is recorded up to a greater distance from surface in case of En-19 steel when compared to En-24 and En-37 steels. The thickness of compound layer that can be observed in microstructures given in fig-2 confirms this pattern of behaviour. The hardness pattern of En-19, En-24 and En-37 steels given in fig-3, indicates three distinct zones of hardness. First one with very high hardness of the order of around 900 VHN up to a distance of less than 50 microns -indicating compound layer. Second one- a zone of medium hardness ranging from 350 to 750VHN-indicating the diffusion zone. Third one -a zone that has hardness more or less similar to untreated sample-indicating the unaffected core zone. Diffusion zone thickness ranges from 100 to 200 microns. However exact thickness of diffusion zone can be properly controlled by maintaining appropriate quantity of alloying elements.These findings are in line with the earlier research reports[9-11].

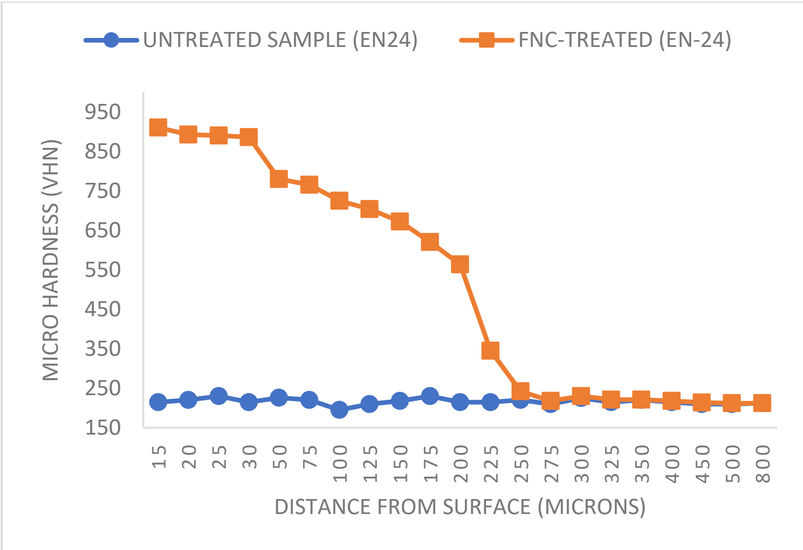

Fig. 3. (a): Comparison of micro hardness profiles of un treated and FNC treated En-19 steel.

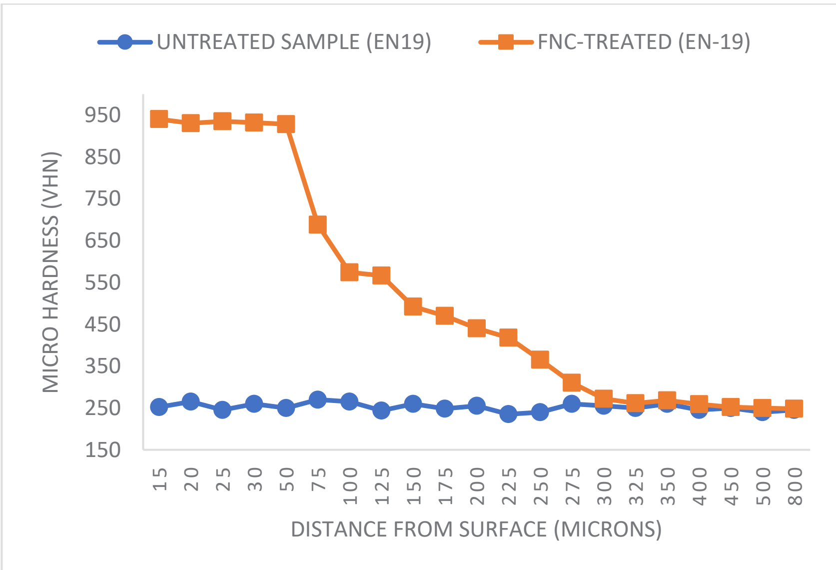

Fig. 3. (b): Comparison of micro hardness profiles of un treated and FNC treated En-24 steel.

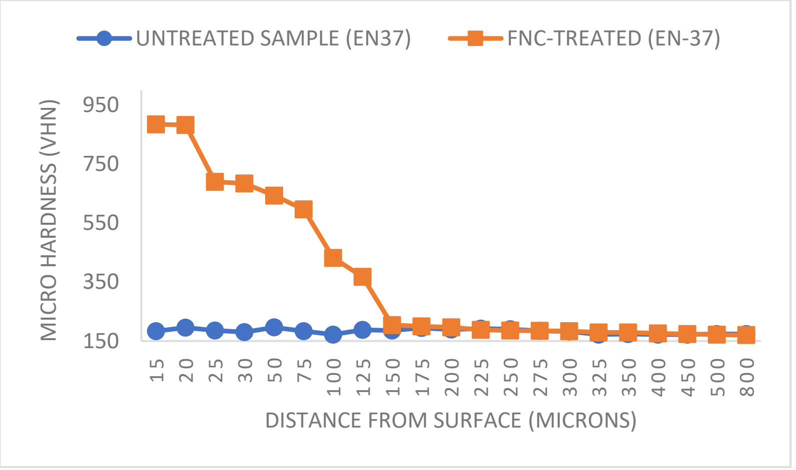

Fig. 3. (c): Comparison of micro hardness un treated and FNC treated En-37 steel.

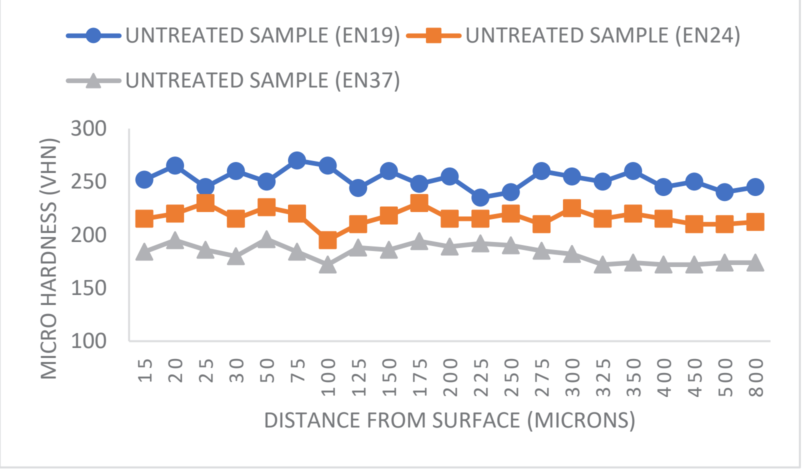

Fig. 3. (d): Comparison of micro hardness profiles of profiles of un treated En-19,En-24 and En-37 steels.

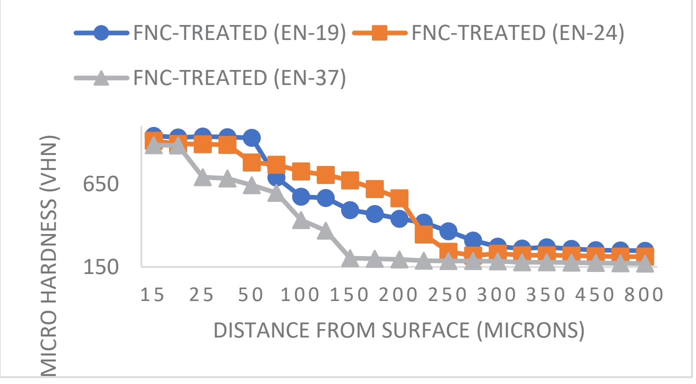

Fig. 3. (e): Comparison of micro hardness profiles of FNC treated En-19,En-24 and En-37 steels.

7 Wear Studies

To study the effect of Ferritic nitro carburising on wear behaviour of En-19, En-24 and En-37 steels, wear investigations are carried out. Pin on disc type of wear testing machine is used for the purpose. The pin material is -samples of En-19, En-24 and En-37 and the geometry of wear test specimen is shown in fig-4(a).Wear studies are made for both untreated and FNC treated samples under dry running condition. High carbon high chromium steel (D2 steel) is chosen as disc material. Wear loss as a function of time is experimentally determined as a function of time. Comparison of wear behaviour of both untreated and FNC treated samples are given in fig-4(b).

It can be observed that FNC treatment improves the wear resistance markedly and the extent of improvement is maximum for En-19 steel. Throughout the experiment the rate of wear of untreated steel is more or less constant. Nonuniform rate of wear is registered in case of FNC treated steels. For En-19 steel rate of wear is high and almost uniform till first 15 minutes where as in case of En-24 steel rate of wear is high in first 10 minutes but in case of En-37 steel high wear rate is registered in first 5 minutes. Beyond the times mentioned above the rate of wear is increased markedly for all the samples under consideration. The compound layer observed in microstructure, which belived to contain epsilon carbo nitride, can be attributed for high wear resistance in the initial times. Once this compound layer is worn out, the diffusion zone and then core of the specimen are exposed to wear load and hence records higher wear rate.

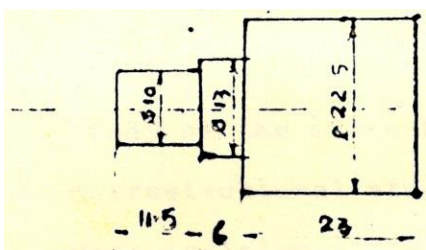

Fig. 4. (a)Wear test specimen

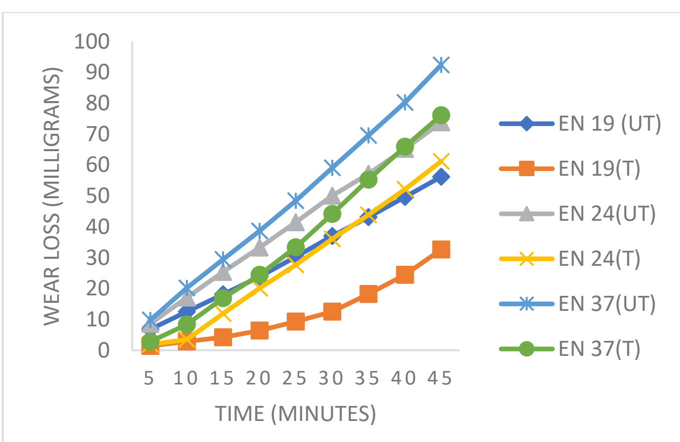

Fig. 4. (b)Comparison of wear behaviour of untreated and FNC treated samples of En-19,En-24 and En-37 steels.

8 Conclusions:

- Ferritic nitro carburizing markedly improves the surface hardness.
- The thickness of compound layer formed and its ability to withstand wear depends on composition of steel.
- When compared to En-24 and En-37 steels the ability of En-19 steel to form compound layer during FNC treatment is more and hence FNC treated En-19 steel exhibits superior surface hardness and hence high wear resistance compared to En-24 and En-37 steels.

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