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Modification of EN9 Steel Surface by Salt Bath Nitrocarburizing Process

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ABSTRACT
Nitrocarburizing is a thermochemical treatment which involves the diffusional addition of nitrogen and carbon to the surface of ferrous materials. Usually carried out at temperatures within the ferritic phase field of the Fe-N-C system, i.e. below 593 °C, the treatment improves the resistance to scuffing through the development of a compound layer at the surface consisting predominantly of epsilon carbonitride, Fe2.3(C,N). The treated components also exhibit enhanced fatigue properties on account of the diffusion zone where nitrogen is held in solid solution beneath the compound layer. Nitrocarburizing is therefore applied advantageously to textile machinery components, water pump parts, timing gears and a number of automotive parts which undergo sliding-rolling. The aim of the present research is to investigate the effects of salt bath nitrocarburizing on the EN 9 steel. An increase in wear resistance and impact strength has been found, whereas a very slight variation in microhardness has been reported.

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Introduction

EN9 is a medium carbon steel grade commonly supplied in the as rolled condition. It can be flame or induction hardened to produce a high surface hardness with excellent wear resistance for a carbon steel grade [1]. EN9 is general engineering applications including blades for axes, knives, and sickles as well as shafts, bushes, crankshafts, screws, and wood working drills. In the normalized condition EN9 can be used for gears, sprockets and cams [2]. Modification of steel surface by salt bath or gaseous nitrocarburizing is a process that is widely used in manufacturing of machine components and tools, since an improved surface hardness, fatigue strength and corrosion resistance [3] at elevated temperatures, can thus be achieved at minimum distortion [4].When it comes to hardening of metals the Nitriding/Nitrocarburizing treatments are the most promising and they lead to thick and compact protective layers of nitrogen and carbon [5]. Nitriding/ Nitrocarburizing process is done in three media; Liquid, gas, and plasma Nitrocarburizing [6]. . Higher treating temperatures produce much thicker nitride layer or, in other words, permit distinct reduction in treating time [7]. Some of the researchers studied the nitrocarburizing process, brief details are as follows. Marcos Pérez and Francisco Javier Belzunce (2016) [8]: Studied two thermochemical surface treatments (salt-bath nitrocarburizing and nitriding followed by post-oxidation) applied to a H13 steel. The effect of a deep cryogenic treatment on wear resistance has also been assessed. Zhengshou Zhou et al. (2015) [9]- developed a DC salt bath nitrocarburizing technology by additionally applying direct current (D.C.) electric field on the basis of traditional technique (NM).

The authors found that thickness of compound layer increased more than 60%, from 18μm to 29μm. Zhengshou Zhou et al. (2014) [9]- developed a novel rapid salt bath nitrocarburizing technology by additionally applying direct current (D. C.) electric field on the basis of traditional technique (NM). Yunsong Niu et al. (2014) [10] prepared a novel kind of oxide film on the Mg–Gd–Y–Zr alloy by mixed molten-salt bath treatment. Runbo Huang et. al. (2013) [11]-studied the modification of 2205 stainless steel by salt bath nitrocarburizing at 430 0C.

J. W. Zhang et al. (2011) [12] studied the nitrocarburizing and post oxidation of 35CrMo alloy steel in cyanate bath and nitrate–nitrite salt bath respectively. P. Jacquet et.al. (2011) [13] studied two different grades of steel, DC 04 (non alloyed steel) and 15CrMoV6 (alloyed steel); both of them were salt bath nitride with QPQ process. K. Marušić et. al. (2006) [14] modified the surface of carbon steel samples using nitrocarburizing in a salt bath, with or without post-oxidation. Franjo Cajner et. al (2003) [15] performed the comparative testing of properties for the steel grade Ck45 (AISI-1045) after salt bath nitrocarburizing (TENIFER process) without and with post-oxidation (TENIFERQPQ process). Y. H. Qianget. al. [16].

This paper explores salt bath nitrocarburizing and nitrocarburizing-quenching duplex treatment technologies. For comparison, a quenching-tempering treatment was also conducted.

Experimental

Materials and Methods

EN-9 steel (Table 1) will be used for the present study, due to its high mechanical strength qualities. EN9, also known as 070m55, available in diameters, flats, squares and plates with a carbon content 0.50/0.60 this is a medium carbon steel which can develop a tensile strength of 700N/mm 45tsi.

Table 1: Chemical Composition of EN 9 steel

Element	Min	Max
Carbon, C	0.50	0.60%
Manganese, Mn	0.50	0.80%
Silicon, Si	0.05	0.35%
Sulfur, S	-.--	0.06%
Phosphorous, P	-.--	0.06%

The process parameters were shown in the table 2 and are carefully chosen after studying the literature. Table 3

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shows the design of experiments used for current research. As we have already studied nitrocarburizing process is a thermal diffusion process, dissociation of carbon and nitrogen from cyanate bath was performed in a nitrocarburizing furnace according to the chosen parameters. Before nitrocarburizing, the flat surface of each sample was grind by sand paper and cleaned with acetone, alcohol and distilled water in succession. Then the samples of EN9 steel were dipped in the molten salt bath according to the design of experimentation. After nitrocarburizing, the samples were cooled down slowly in air to room temperature and were cleaned in alcohol bath for15min.

Table 2: Input parameters

Sr. no	Factor	Level1	Level2	Level3
1	Nitrocarburizing time (min.)	70	90	110
2	Pre-Heating temp. (oC)	300	350	400
3	Pre-Heating time. (min.)	10	20	30

Table3: Design of experiments

Run	Environment	Nitrocarburizing time (min.)	Pre-Heating temp. (°C)	Pre-Heating time. (min.)
1	Untreated			
2	Nitrocarburized	70	300	10
3	Nitrocarburized	70	350	20
4	Nitrocarburized	70	400	30
5	Nitrocarburized	90	300	30
6	Nitrocarburized	90	350	20
7	Nitrocarburized	90	400	10
8	Nitrocarburized	110	300	20
9	Nitrocarburized	110	350	30
10	Nitrocarburized	110	400	10

Results and Discussion

Influence of Nitrocarburizing process on Microhardness

Main effects plot for s/n ratio for Micro-hardness has been plotted by taking values from observation Table 3. Total 9 samples were treated and specimens were prepared for Micro- hardness testing. Graphs clearly reveal the significant effect of Nitrocarburizing process on EN9 steel. Hardness of materials is desired in many applications which ultimately enhance the wear properties of components. The signal to noise ratio analysis resulting in the optimum machining parameters for microhardness is presented in the Figure 1. accordingly, the combination recommended for the best micro-hardness outcome is the nitrocarburizing time 110 minutes, Preheating temperature 400 degree Celsius, preheating time 20 minutes. The nitrocarburizing time is ranked number 1 according to the response table for S/N ratio.

Table 3: S/N Ratio table for Microhardness

Level	Nitrocarburizing time (min.)	Pre-Heating temp. (C°)	Pre-heating time. (min.)
1	52.86	53.63	53.4
2	53.77	53.82	54.01
3	55.01	54.19	53.90
Delta	2.15	0.56	0.27
Rank	1	2	3

Influence of Nitrocarburizing process on wear

The graph for wear resistance has been plotted by taking values from observation Table 4. Total 9 samples were treated and specimens were prepared for wear testing. The result reveals that Nitrocarburized samples have high wear resistance and lost less weight as compared to untreated sample. The signal to noise ratio analysis resulting in the optimum machining parameters for wear is presented in the Figure 2. accordingly, the combination recommended for the best wear outcome is the Nitrocarburizing time 90 minutes, Preheating temperature 300 degree Celsius, preheating time 10 minutes. The Nitrocarburizing time is ranked number 1 according to the response table for S/N ratio.

Table 4: Response Table for S/N Ratios for wear

Level	Nitrocarburizing time (min.)	Pre-Heating temp (C°)	Pre-heating time (min.)
1	18.69	18.48	18.79
2	18.20	19.75	19.61
3	20.95	19.61	19.45
Delta	2.75	1.27	0.82
Rank	1	2	3

Influence of Nitrocarburizing process on Impact-strength

The impact strength was tested on charpy impact testing machine. Graph explains the results very well. It has been found that impact strength has been increased when samples were introduced to Nitrocarburizing process. The s/n ratio analysis resulting in the optimum machining parameters for impact strength is presented in the Figure 3.accordingly,the combination recommended for the best impact strength outcome is the Nitrocarburizing time 110 minutes, Preheating temperature 400 degree Celsius, preheating time 30 minutes. The Nitrocarburizing time is ranked number 1 according to the response table no. 5 for S/N ratio.

Table 5: Response table for S/N ratio for Impact strength

Level	Nitrocarburizing time (min.)	Pre-Heating temp. (C°)	Pre-heating time (min.)
1	50.62	51.35	51.47
2	51.94	51.56	51.55
3	52.24	51.88	51.78
Delta	1.63	0.53	0.32
Rank	1	2	3

Conclusions

Present research has been done on the investigation of effects of salt bath Nitrocarburizing process on EN-9 steel. After the completion of experiment, wear resistance, impact strength and microhardness were tested, and results were analyzed and discussed. From the present research following conclusions can be made-

1. From the results of wear resistance test, very less wear has been reported as compared to untreated specimen. Thus it can be concluded that, salt bath nitrocarburizing process can improve the wear resistance properties of EN-9steel.
2. Microhardness test revealed that a little increase in microhardness has been found. Microhardness is a desirable property, with the increase in nitrocarburizing temperature, an increase in microhardness has been reported. It can be concluded that with the increase in temperature, microhardness can be increased.
3. Impact strength of the specimens was also tested, and an increase in impact absorbing energy has been found

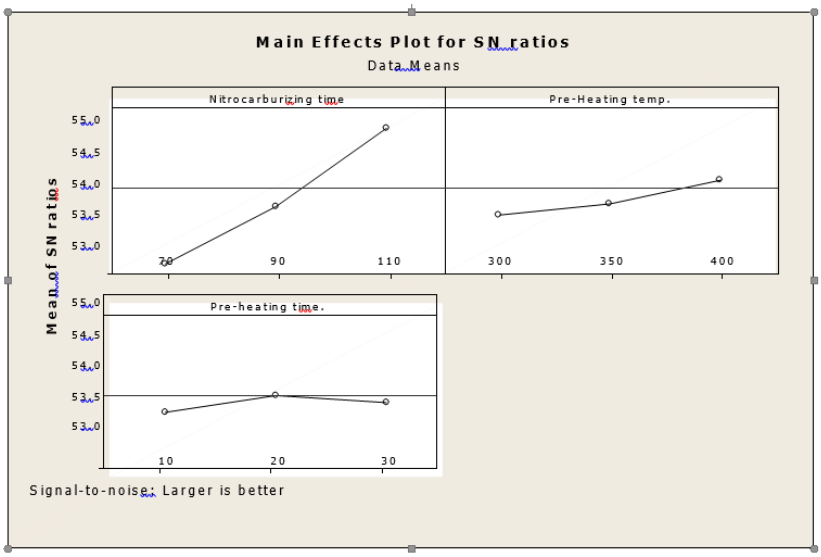

Figure1: Main effects plot for s/n ratio for Micro-hardness

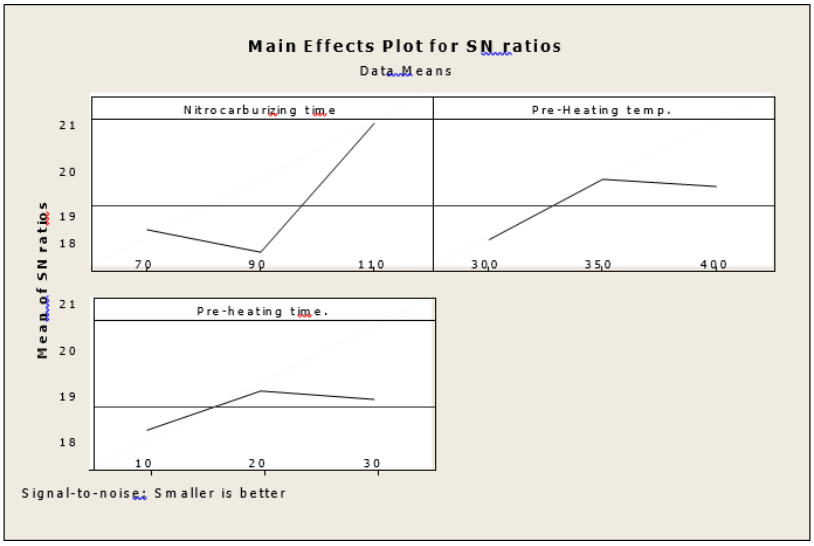

Figure 2: Main effects plot for s/n ratio for wear

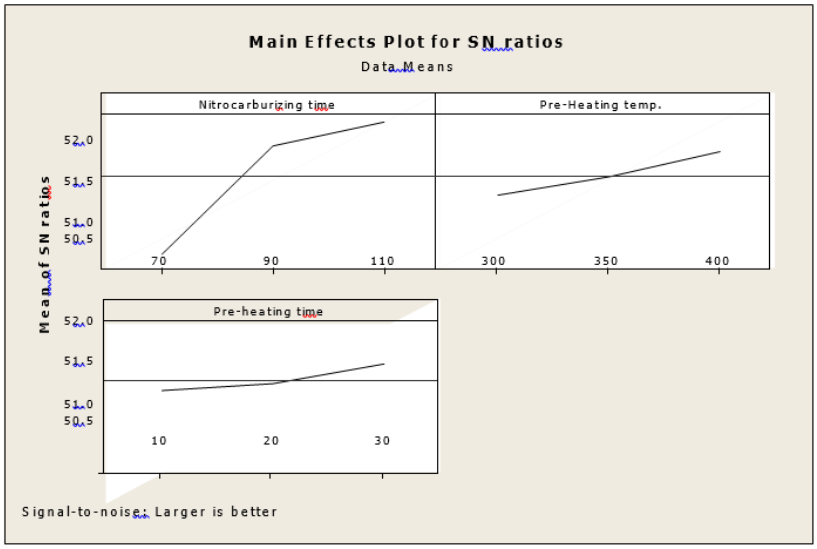

Figure 3: Main effects plot for s/n ratio for Impact strength

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when treated with salt bath nitrocarburizing. It could have happened due to proper diffusion layer formation over the EN9 steel specimen surface. High impact strength is always a desirable property. Thus it can be concluded that salt bath nitrocarburizing can be used to improve impact strength of steel.

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