Performance Evaluation of Mechanical Properties of EN41B using Gas Nitriding Process

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Abstract— The main objective of this project is to develop and establish a gas nitriding process and investigation of Gas nitriding characteristics of most commonly used EN41B alloy steel. Gas nitriding process is heat treatment process used for improving wear resistance, corrosion resistance and to improve mechanical properties almost applied to the range of steels containing nitride-forming elements such as chromium, molybdenum, vanadium and aluminium. With the use of furnace the gas nitriding process is possible by using different input parameter as Process control, Process chamber maintenance, Time, Temperature, Gas activity control, Gas flow, Carbon content, Furnace temperature etc, and observe its effects on output parameter like layer thickness, hardness, wear resistance, corrosion resistance, mechanical properties. To perform the experiment, an experimental design matrix was constituted using the design of the experiments.

Key words: Hardness, Yield Strength, Ultimate Strength, Gas Ntriding, Taguchi

I. INTRODUCTION

The heat treatment includes heating and cooling operations or the sequence of two or more such operations applied to any material in order to modify its metallurgical structure and alter its physical, mechanical and chemical properties. Usually it consists of heating the material to some specific temperature, holding at this temperature for a definite period and cooling to room temperature or below with a definite rate. Annealing, Normalizing, Hardening and Tempering are the four widely used heat treatment processes that affect the structure and properties, and are assigned to meet the specific requirements from the semi-fabricated and finished components. Steels being the most widely used materials in major engineering fabrications undergo various heat treatment cycles depending on the requirements. Also aluminum and nickel alloys are exposed to heat treatment for enhancement of properties.

II. LITERATURE REVIEW

C. Medrea et all presented mechanical and structural properties of AISI 1015 carbon steel nitrided after warm rolling. They showed Nitriding of the steel after warm rolling gives a hard surface layer which presents a significant improvement of wear resistance. In the same time, the core preserves its fine grain microstructure with improved tensile properties as compared to untreated pieces. Nitriding of steel after warm rolling leads to increased wear resistance of parts made from low carbon steel and implicitly to increasing their lifetime. [1]

L. Ceschini et all focuses on the dry sliding behaviour of Low temperature carburising (LTC)-treated AISI316L austenitic stainless steel against several counter materials (AISI316L, LTC-treated AISI316L, hard chromium or plasma-sprayed Al_2O_3–TiO_2). They showed that the LTC produced a hardened surface layer (C-supersaturated expanded austenite), which improved corrosion resistance in NaCl 3.5% and increased wear resistance, to an extent which depends on both normal load and counter material. It has been obtained that the LTC did not improve the behaviour in terms of friction.[2]

H. Sert et all investigated wear behaviour of cam spindles made of five different surface treated nodular cast iron (GGG50) and induction hardened CK45 steels. They used PVD–TiN-coated, both borided and PVD–TiN-coated, only hardened, both hardened and PVD–TiN-coated and only borided spherical graphite cast iron and induction hardened CK45 in experiment. They were conducted wear behavior of two type of steel to observed using cam wear mechanism under unlubricated and six different surface treatments. From experiments, they come to concluded that the surface treatments increased the wear resistance of GGG50 material.[3]

Enver Atık et all investigated effects of conventional heat treatment and boronizing on SAE 1010 and SAE 1040 structural steels, D2 tool steel, and 304 stainless steel. They took various heat treatment process like carburisation, nitriding, transformation hardening and boronizing to the specimens for investigated layer thickness, corrosion and wear strength. They found that the 3. Hardness value results show that there was not a linear relationship between hardness values and wear and that high values of hardness affect the wear negatively in D2 and 304 steels. They found that the micro hardness values, corrosion resistances and wear strengths of borided specimens were higher than for other specimens. In this tribological system, it has been found that wear strengths were not directly related to the layer thicknesses, hardnesses and corrosion resistances. [4]

III. EXPERIMENTAL PROCEDURE

Parameters	Unit	Level 1	Level 2	Level 3
Nitriding temperature	ºC	480	500	520
Soak time	Hour	10	11	12
Ammonia flow rate * 10^8	mm^3/hr	48	54	60

Table 1: Range Of Process Parameters

For the process parameters level selection, priority was given to industrial applicability. In industrial applications, the overall processing time is particularly important to minimize total costs. For this reason, to find out which factors influence the material properties, the holding time varied between 10 to 12 h. The effect of the cooling rate time investigated in detail through number of experiments. Also carbon content play vital role in variation of hardness of material. In this investigation carbon content has been considered for hardness value.

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IV. RESULT AND DISCUSSION

No.	Nitriding temperature [°C]	soak time [Hrs]	ammonia flow rate [mm^3/hr]	Yield strength [N/mm^2]	Tensile strength [N/mm^2]	Hardness [BHN]
1	480	10	48	925	1076	260
2	480	10	54	940	1087	301
3	480	10	60	960	1090	312
4	480	11	48	902	1075	278
5	480	11	54	912	1077	310
6	480	11	60	919	1082	318
7	480	12	48	892	1080	290
8	480	12	54	900	1083	322
9	480	12	60	902	1090	329
10	500	10	48	918	1071	270
11	500	10	54	931	1082	312
12	500	10	60	942	1087	319
13	500	11	48	897	1068	287
14	500	11	54	901	1072	318
15	500	11	60	910	1080	322
16	500	12	48	891	1078	310
17	500	12	54	892	1079	329
18	500	12	60	894	1080	349
19	520	10	48	912	1067	277
20	520	10	54	926	1080	311
21	520	10	60	933	1088	321
22	520	11	48	882	1062	300
23	520	11	54	905	1070	318
24	520	11	60	918	1073	328
25	520	12	48	875	1077	319
26	520	12	54	890	1072	349
27	520	12	60	881	1074	370

Table 2: Experiment result

A. *Main Effects Plot for SNR of Yield Strength*

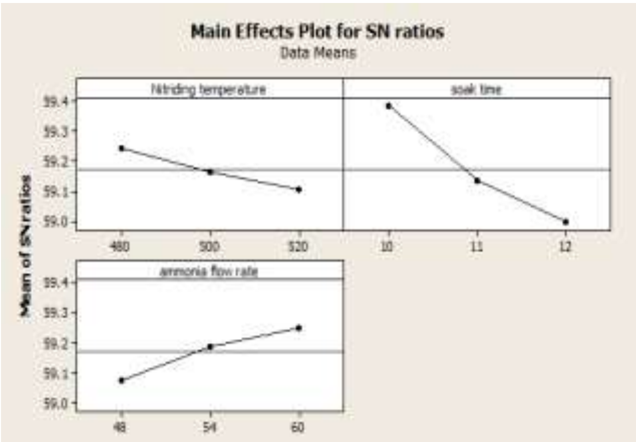

Fig. 1: Effect of control factor on yield strength

B. *Main Effects Plot For SNR Of Tensile Strength*

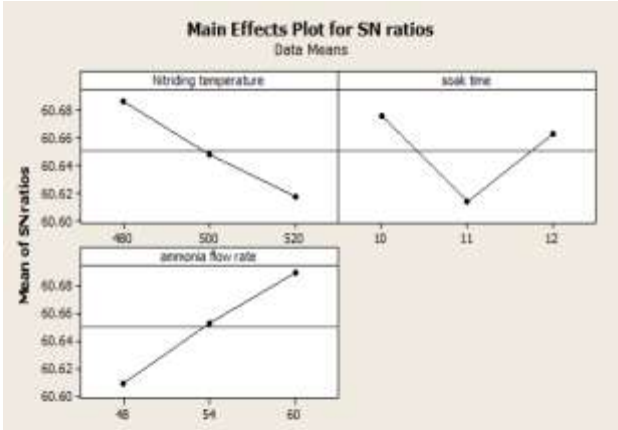

Fig. 2: Effect of control factor on Tensile strength

C. *Main Effects Plot for SNR Hardness*

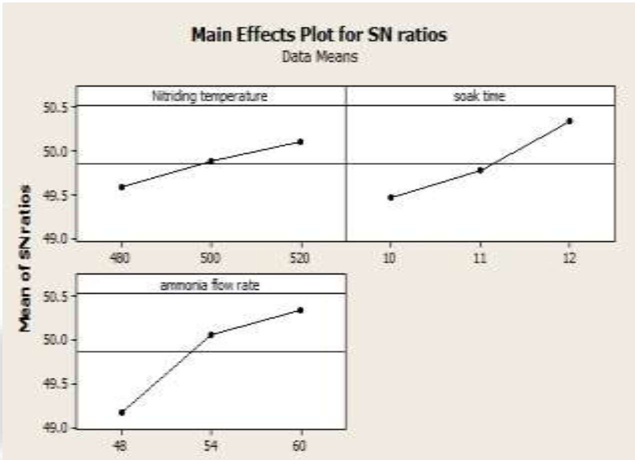

Fig. 3: Effect of control factor on hardness

V. OPTIMIZATION

A. *Grey Relational Analysis*

Sr No.	Grey relational coefficient [GRC]			Grey relational grade [GRG]
	Yield strength	Tensile strength	Hardness	
1	0.459459	0.5	1	0.653153
2	0.395349	0.358974	0.572917	0.442413
3	0.333333	0.333333	0.514019	0.393562
4	0.611511	0.518519	0.753425	0.627818
5	0.534591	0.482759	0.52381	0.51372
6	0.491329	0.411765	0.486726	0.463273
7	0.714286	0.4375	0.647059	0.599615
8	0.62963	0.4	0.470085	0.499905
9	0.611511	0.333333	0.443548	0.462798
10	0.497076	0.608696	0.846154	0.650642

11	0.431472	0.411765	0.514019	0.452418
12	0.388128	0.358974	0.482456	0.409853
13	0.658915	0.7	0.670732	0.676549
14	0.620438	0.583333	0.486726	0.563499
15	0.548387	0.4375	0.470085	0.485324
16	0.726496	0.466667	0.52381	0.572324
17	0.714286	0.451613	0.443548	0.536482
18	0.691057	0.4375	0.381944	0.5035
19	0.534591	0.736842	0.763889	0.678441
20	0.454545	0.4375	0.518868	0.470304
21	0.422886	0.35	0.474138	0.415675
22	0.858586	1	0.578947	0.812511
23	0.586207	0.636364	0.486726	0.569765
24	0.497076	0.56	0.447154	0.50141
25	1	0.482759	0.482456	0.655072
26	0.73913	0.583333	0.381944	0.568136
27	0.876289	0.538462	0.333333	0.582695

Table 3: Grey Relational Coefficient

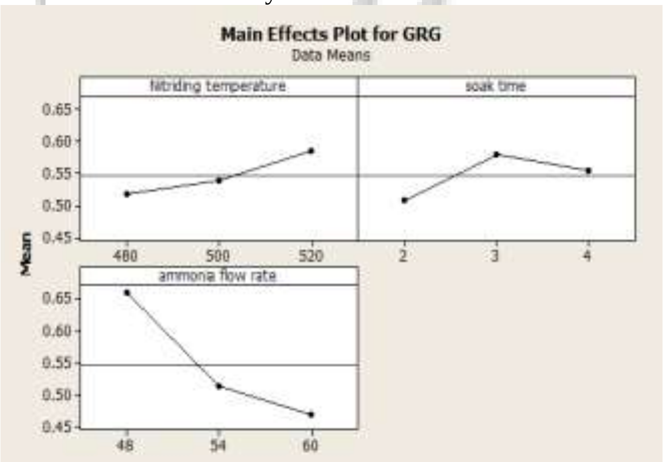

Fig 4: Main effect of factor on Grey Relational Grade

Symbol	Control factor	Level 1	Level 2	Level 3
A	Nitriding temperature	0.51736	0.53895	**0.58378**
B	Soak time	0.50738	**0.57932**	0.55339
C	Ammonia flow rate	**0.65846**	0.51296	0.46868

Table 4: Main effect of factors on Grey Relational Grade

VI. Conclusion

The EN41B has been cut nitride by gas nitriding process. The conclusions relevant to this investigation are outlined below:

1) The yield strength increase with increase ammonia flow rate from 48 to 60 m^3/hr., when the other two parameter are kept constant as well as yield strength decrease with increase nitdring temperature and soak time 480 to 520 °C and 2 to 4 hr respectively.
2) While studying the effect of the procee parameters on the yield strength, it was observed that soak time play crucial roles in the effect on the yield stength. The role of the both the nitriding temperature and ammonia flow rate is not crucial to the same extent.
3) Contribution of Ammonia flow rate are very high on tensile strength and hardness. Thus it has been seen that value of ammonia flow rate should high for desirable value of tensile strength and hardness.
4) Through use of regression equation, engineer can manipulate range of process parameters for this particular work- material. Also it has been find out and predicted yield strength, tensiles strength and hardness at any combination of process parameter.
5) The response table of Taquchi-Grey method analysis was used to optimize the effect of process parameters on EN41B. The highest grey relational grade of 0.8125 was observed in experiment run 22 which indicates that the optimal combination of control factors for mentioned responses.
6) The optimal parameter values are at nitring temperature 520 °C, soak time 3 hrs and ammonia flow rate 48 m3/hr. At these parameters the values of yield strength 882 MPa, tensile strength 1062 MPa and hardness 300 BHN respectively.

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