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Piston Rod Defect Analysis and Actions to Overcome the Defects

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Abstract

Nitriding is a case hardening thermo-chemical process used in many applications today. Nowadays, the improvement of ferrous materials performance is a problem of high interest. One of well-known wear and corrosion properties improving technique is plasma nitriding, in which elemental nitrogen is introduced to the surface of a metal part for subsequent diffusion into the material. As a result, a compound, “white” layer and a diffusion zone are formed at the surface. A literature research was done in order to study the nitriding mechanism and different nitriding methods used in industry. This paper is related to piston rod porosity defect. Porosity i.e. small pits are ocurred on piston rod surface after plasma nitriding. The material used here is AISI 4340 steel. Plasma nitriding of alloy steel, grade AISI 4340, was carried out at different temperatures, keeping other processing parameters constant. But defect is not reduced. So alternative methods, materials, defect minimization techniques, defect causes & its minimization are discussed in this paper. The experiments were carried out on piston rod samples which were plasma nitrided with formation of varying amount of thickness of compound white layer and maintaining diffusion layer depth the same. The characterization of samples was done in respect of chemical composition, microstructure & micro-hardness. The characterization of the plasma nitride samples was carried out using different analysis techniques X-ray diffraction, SEM. Metallographic and chemical analysis were done in order to determine the influence of microstructure defects on the hardness plasma nitrided steel in industrial conditions. The microstructure was observed by optical microscope before and after each nitriding method. The hardness of specimens was measured before and after each treatment. The effect of temperature on the surface roughness, hardness, and microstructure was investigated along with their corrosion resistance.

Keywords- Plasma Nitriding, AISI 4340 Steel, AISI 4140 Steel, Hardness, Porosity Defect

I. INTRODUCTION

Nitriding is defined as the thermo-chemical treatment of a workpiece in order to enrich the surface layer with nitrogen. It is a method of surface hardening using dc glow discharge technology to introduce elemental nitrogen to the surface of metal part for subsequent diffusion into the material. The ion nitriding process which is applied to ferrous materials has been extensively used to improve the surface properties, wear, fatigue, corrosion and friction properties and also load bearing capacity of dynamically loaded components.

A. Problem Statement

After Plasma nitriding process on piston rod, there are small pits i.e. porosity defect ocurrs on nitrided surface of piston rod. This project aim is to overcome this defect & make piston rod defects free.

B. Scope

The plasma nitriding is one of the thermo-chemical process used to harden the surface of steel. In this process, nitrogen diffuses from the surface, similar to other nitriding processes, and forms various nitrides. The type & concentration of nitrides formed depends upon the gas composition, temperature & duration of nitriding.

Due to uniformity, complex geometry shapes can also nitrided. Plasma nitriding least affects the surface finish of the product. After doing plasma nitriding higher surface hardness maintained due to which Martials core properties doesn’t gets affected. By this process material surface gets excellent wear resistance. It produces a compound zone which is dense, nonporous, very hard, and non-brittle and has low coefficient of friction. This process has least process gas consumption & clean emissions usually hydrogen and nitrogen. Also process has shorter cycle time and good friction, wear and fatigue properties. Due to this factors and many advantages this process is generally preferred by industries.

C. Objective
The main aim of this paper is to overcome this porosity and pitting defect after nitriding. For this metallurgical failure analysis after Plasma/Ion Nitriding on piston rod is need to do, the followings are the main objectives of project.
1) To check whether the defect is in material composition or in other factors
2) To identify defect ocurred after which process i.e. before nitriding or after nitriding
3) To find different techniques to overcome defects & make significant improvement in throughout process, average lead times reduce and increase products quality.

D. Methodology
Piston rod of compressor is manufactured by following steps
1) Material cutting
   First circular cross section rod material is cut for desired length after taking material from vendor.
2) Centering (Pre Turn)
   Workpiece is put into the chuck and end faced off, then centre drilled by keeping 3-4 mm allowance to provide small tapered hole which can accommodate and be supported by a running centre in the tailstock. In four jaw chuck, centering is done by adjusting each jaw to get workpiece in desired axis.
3) Finish Turning
   Turning is a machining process in which cutting tool describes helix tool path by moving more or less linearly while rod rotates. Tools axes may move in straight line or along some set of cure or angle, but essentially it move linear.
4) Thread Rolling
   It is used to produce strong, smooth, precise and uniform external thread forms. Piston rod is rolled between three rollers to produce external threads on it
5) Grinding
   Center less grinding permits to develop the correct pitch diameter prior to roll thread and control diameter within 20 microns. It is abrasive machining process that uses a grinding wheel as the cutting tool. Different varieties of machines can be used for grinding, but it depends on application. Grinding process provides diameter with very fine finish and very accurate dimensions. It is suited to machining of very hard materials than regular machining.
6) Heat Treatment
   After all process done on material piston rod get manufactured. Next step is heat treatment. In this material is oil quenched. Quenching is a rapid cooling of a workpiece to obtain certain material properties. It prevents undesired low temperature processes such as phase transformations. It reduces crystal grain size of metallic materials by increasing their hardness.
7) Mechanical Testing
   After completing all process, mechanical properties such as tensile and chemical properties are tested. Also tensile strength, material composition of piston rod is studied in details and readings are recorded.
   After manufacturing piston rod, plasma nitriding process is done on piston rod. Before that again pre heat treatment, material cleaning, metallographic preparation is required.

II. LITERATURE REVIEW

In the early years of 20th century, Adolph Machlet worked as a metallurgical engineer for USA. He got patent for “The Nitrogenization of Iron and Steel in an Ammonia Gas Atmosphere into which an Excess of Hydrogen Has Been Introduced”. He recognized that surface hardening technique of carburizing led to distortion problems due to extended periods at elevated temperatures, followed by severe quenching into either water or oil. Through experimentation, Machlet discovered that nitrogen was very soluble in iron. Nitrogen diffusion produced a relatively hard surface in simple plain irons or low-alloy steels and significantly improved corrosion resistance. This was accomplished without subjecting steel to elevated temperatures and, more importantly, without cooling steel rapidly to achieve a hard wearing surface. It could now cool freely within process chamber, while still under protection of nitrogen-based atmosphere. It reduces risk of distortion by producing a hard,wear resistant surface with good corrosion resistance. Ammonia was decomposed, or “cracked,” by heat to liberate nascent nitrogen necessary for process. He did decomposition control by using hydrogen as a dilutant gas to reduce amount of available nascent nitrogen. This control of the process gas is known as the “white layer” or “compound zone.”

In 1906 Adoloh Fry the German scientist recognized that nitrogen was very soluble in iron at an elevated temperature. He also recognized that alloying elements strongly influenced metallurgical and performance results. He used a technique similar to that of Machlet, where nitrogen source had to be cracked by heat to liberate nitrogen for reaction and diffusion. Fry used ammonia as source gas, but he did not use hydrogen as a dilutant gas. Thus was developed single-stage gas nitriding process. Fry then investigated the effects of alloying elements on surface hardness. He discovered that nitriding process produced a high surface hardness only on steels containing chromium, molybdenum, aluminum,vanadium, and tungsten, all of which form what are known as "stable nitrides." He also discovered the critical nature of process temperature in terms of case depth and surface metallurgy. Processing the steel at higher temperatures placed surface at risk to form a saturated solution of nitrogen in immediate surface of formed case. Steels with higher alloy contents were not readily available for nitriding. Fry developed a group of steels known as the "Nitralloy" group. These steels, specifically designed as nitriding steels, soon became internationally recognized. Even today the Nitralloy steels are specified.

In 1920 Thomas Firth and John Brown started company Firth Brown Steels which works under British Standard Nitriding Steels. They developed a group of nitriding steels under the licensed guidance of Krupp Steels under brand name of Nitralloy. The steels from Firth Brown were known as "LK" group, designated by British Standard 970 as En 40 A, En 40 B, En 40 C, En 41 A, & En 41 B. Developed for nitriding applications. These were chromium-molybdenum steels.The En 41 series contained aluminum, which produced a much higher surface hardness after nitriding. Aluminum has a strong affinity for nitrogen, forming very hard aluminum nitrides that are quite stable in amounts up to 1.0% Al. Much above 1.0%, aluminum has no effect on resultant nitriding hardness.

Metallurgists H.W. McQuaid and W.J. Ketcham conducted a series of investigations to evaluate the new nitriding process at the Timken Detroit Axle Company in Detroit. They focused on process temprature. The temperatures selected ranged from 540 to 650 °C.The upper temperature was significantly lower than temperatures employed by Machlet, which ranged from 480 to 980 °C. McQuaid and Ketcham concluded that higher nitriding temperatures had an effect on core hardness of alloy steels but little effect on the ability to nitride at those temperatures. They also found that higher process temperatures increased the risk of forming nitride networks, particularly at corners, due to the higher solubility of nitrogen in iron. When present, nitride networks cause premature failure at steel surface by cracking and exfoliation. They concluded that nitriding was much easier to control than carburizing. They also found that the corrosion properties of low-alloy and alloy steels were much improved while undergoing salt spray tests and that practically any steel can be nitrided, including plain carbon steel and pure iron. They concluded that the "white structure" is composed of a nitride, either iron nitrides or a complex nitride layer, involving both iron and alloying elements. A further conclusion was that the white layer or compound zone was extremely hard but very brittle and that the layer should be avoided if possible. They also studied the effect of decarburization on nitrogen diffusion and the mechanical strength of the nitrided case. Their results showed that the steel to be nitrided should clearly be free of surface decarburization; otherwise, the nitrided surface will exfoliate and peel away from the substrate. They concluded that rough machining or some other operation to ensure complete removal of any decarburized surface layer should be performed before carrying out any nitride operation.

Robert Sergeson was associated with the research laboratories of the Central Alloy Steel Corporation in Canton, Ohio. He presented a paper in July 1929 on steels containing chromium, aluminum, molybdenum, vanadium, and tungsten. Sergeson concluded that process chemistry and process control in nitriding were much simpler than in carburizing. He also reviewed the effect of reheating on the case after nitriding and found that, with increasing temperature, case hardness stability was much better than for carburized and quenched alloy steel. He noted that the surface hardness value for a chromium-aluminum steel began to decrease at only 525 °C. He worked with many more steels and compared the effect of temperature on both nitrided alloy steels and carburized and quenched alloy steels, yielding similar results. Sergeson examined the effect of both temperature and process gas flow on alloy steels and found that if the ammonia gas flow rate was increased at 510 °C, little difference resulted in the immediate surface hardness and case depth. He also found that as process temperature increased, case depth increased but surface hardness decreased. His work covered alloy steels with chromium and aluminum and investigated the effects of varying aluminum and nickel contents. He concluded that nickel was not a nitride-forming element, but that it tended to retard the nascent nitrogen diffusion if present in significant quantities.

III. CASE STUDY

A. Why Nitriding is preferred among all surface hardening methods?

The purpose of nitriding is to improve wear, corrosion and fatigue resistance of constructional parts. These improvements can be understood when looking at the surface microstructure and hardness after treatment. Nitriding is often alternatives to carburizing or carbonitriding. A very important advantage is that nitriding is "low temperature methods" whereas carburizing and carbonitriding are "high temperature methods". By low temperature here is meant a temperature below the one where phase transformation to austenite starts, and high temperature is above the austenite temperature. Nitriding also gives much less distortion of treated parts, which eliminates grinding and therefore shortens the production cycle. Nitriding and nitrocarburizing give unique improvements in corrosion resistance and adhesive wear, which cannot be obtained by carburizing or carbonitriding. Further corrosion resistance improvements are obtained by a oxidation treatment.

B. Why Plasma Nitriding is preferred among all Nitriding Methods?

Nitriding treatments, have been applied to modify the surfaces of stainless steels to obtain high surface hardness by nitriding treatments. Such thermochemical processes as plasma nitriding, gaseous and salt bath nitriding have been investigated and successfully used to produce a nitrogen expanded layer on surfaces of various steels and thus to achieve combined improvements in surface hardness, wear resistance and corrosion resistance. Physical vapor deposition can also be used for improving surface properties, but their application was often limited owing to poor adhesion of coating.

Gas nitriding is an effective chemical heat treatment technique used to introduce nitrogen into metallic materials at certain temperatures and forms hard nitrided layer. In Gas Nitriding surface micro hardness of nitrided steel can reach to HV1000~1200 and wear corrosion resistance can be increased. But shape of the materials cannot be easily altered due to low temperature of gas nitriding treatment.

However Plasma nitriding is one of the most versatile nitriding processes with many advantages over conventional saltbath and gas nitriding. The control of metallurgical properties of nitrided surface is most important advantage of plasma nitriding process, especially for high alloy steels. In this process, parts are immersed in a nitrogen plasma environment, raised to a desirable temperature to facilitate diffusion of nitrogen into bulk substrate until formation of expected nitrides.

C. Precautions before Nitriding

Before nitriding, the components have to be thoroughly cleaned and degreased. Any surface contamination from grinding particles, oil or metal chips will result in an uneven formation of the nitrided layer. This can cause cracks in the coating which leads to flaking and corrosion. After cleaning, the parts are dried and preheated and then transferred to the actual nitriding environment.

D. Design

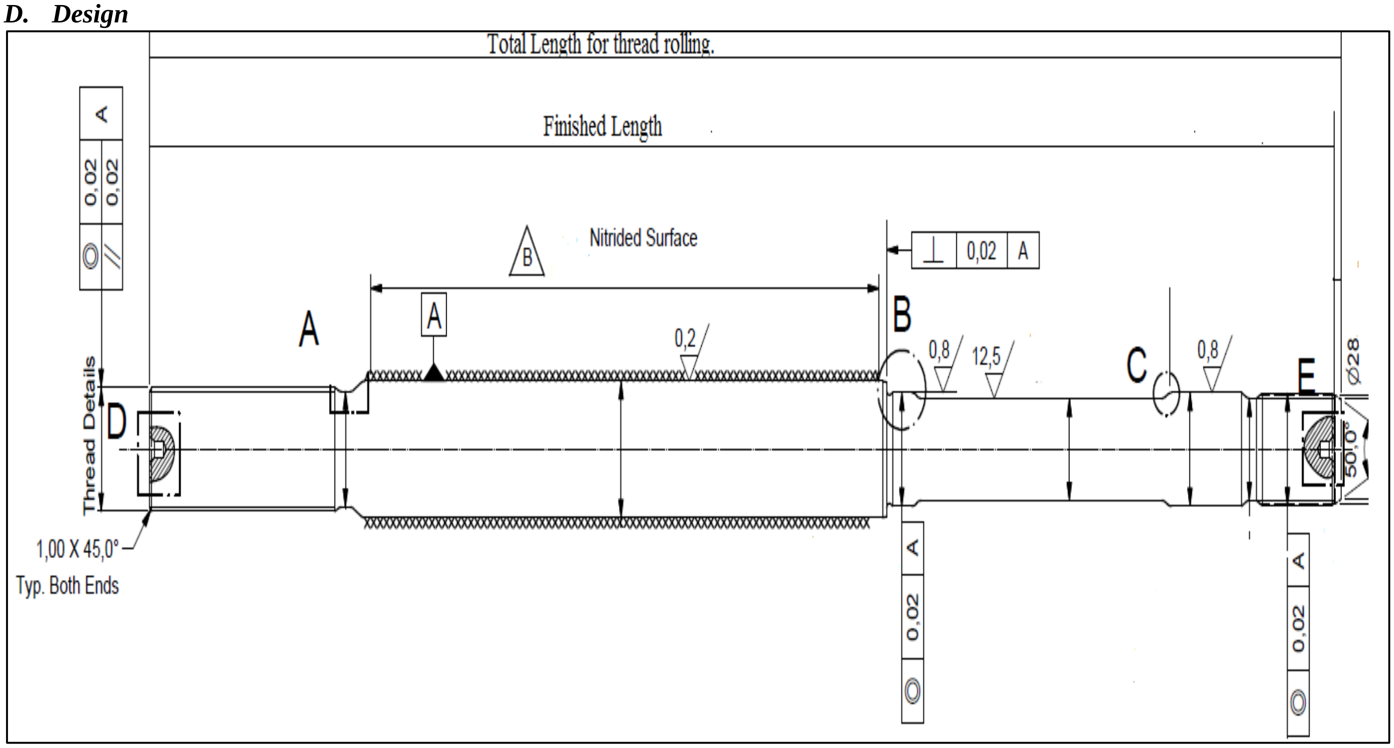

Fig. 1: 2-D Drawing of Piston Rod

1) Design Aspects

Before starting the actual designing, brief study of various aspects of the project was done. The material selection for piston rod was done as per the functional requirement. Maximum parts for assembly work are standard in order to maintain interchange ability. Factors considered for designing are listed below:-

1) Safety, Cost.
2) Wear & Tear.
3) Corrosion Resistance.
4) Material Hardness.

In every industry, safety has the prime importance. Hence while inspecting of compressor piston rod various safety considerations which are taken into account in order to protect machine from wear and corrosion. To avoid wear and tear of compressor, addition coating is done on piston rod by plasma nitriding process.

2) Design Strengths

Following design strength must be considered before designing the piston rod of compressor.

1) Proper Material Selection.
2) High strength-to-weight ratio.
3) High stiffness-to-weight ratio.
4) Good strength with high toughness.
5) High stiffness, yield strength, fatigue strength.
6) Very cheap.

7) Easy to shape & easy to recycle

3) Material used for Piston Rod Manufacturing

For piston rod manufacturing AISI 4340 material is used. But by using this material porosity defect is ocurred on material after plasma nitriding. So testing on AISI4140 is carried out side by side. Material details are discussed in defect minimization techniques.

E. Effect of deferent Alloys on Steel

Alloy steels are broadly classified into two categories:
1) Low alloy steels
2) High alloy steels

In low alloy steels, total content of the alloying elements, such as Cr, Ni, Mo, V & Mn, is kept within 5%. Each alloying element imparts a specific property to the original material. Material selection for piston rod is done according to theie alloy effect. Material must be selected such that there must not get any defect after plasma nitriding process. Effect of each alloy is discussed in following table.

Table 1: Effect of Alloy Elements on Steel

Element	Typical %	Effects
C	0.4	Increase Hardenability and Strength.
Si	High	Acts as Deoxidizer, Improves magnetic properties when present in large %.
Mn	0.2-5	Increse Hardenability & Resistance, Reduce Ductility & Weldability.
P	0.2 - 0.9	Increase Hardenability & Strength low alloy steel, Improves Machinability & Corrosion Resistance.
S	0.08 - 0.15	Improves machinability of very low carbon steels, Normally considered an Impurity.
Cr	4-8	Increase Resistance to Corrosion,Abrasion & Wear, Increases High Temprature Strength.
Mo	2-5	Increase Strength, Toughness, Red Hardness & Hot Strength, When used with (Cr,Mn & V) enhances corrosion & abrasion resistance.
Ni	0.12-0.2	Increase Toughness & Impact Strength, Improve Corrosion Resistance.
Al	Low	Promotes Deoxidization, Promotes Nitriding, Restrict Grain Growth.
B	0.001 - 0.003	Increase Hardenability, Impairs impacts strength slightly
Co	0.5 – 2	Contributes to Red Hardness, Sustains Hardness during Tempering, Increase Hardenability
Cu	0.1 - 0.4	Increase Corrosion Resistance, Counteracts brittleness
Ti	Low	Increases Ausenitic Hardenability, Reduces Martensitic Hardness in Cr Steels.
V	0.15	Increases strength while retaining ductility, Produces fine grain size, Increases Hardenability
W	4	Imparts hardness & wear resistance, Significantly improves red hardness, Imparts strength at high temprature

IV. DEFECT ANALYSIS & MINIMIZATION

A. Porosity

It is almost unavoidable that nitride layer displays a certain degree of porosity. This is due to a recombination to molecular nitrogen in energetically suitable spots, such as grain boundaries, in connecting layer. The connecting layer may be brittle with a tendency to chip and is therefore removed by means of grinding in some cases. The adjacent diffusion zone affects strength characteristics (fatigue resistance) and increases resistance against rolling wear and abrasion. Generally porosity is greater for low alloy steels as compared to high alloyed steels. Alloy content is most important factor for the diffusion zone hardness.

Fig. 2: Piston Rod Defect Photograph (Porosity)

Porosity Defect in piston rod of compressor is occurred after nitriding process due to many reasons. The porosity defect can be reduced by doing certain changes. This changes are as follows.
1) By changing material
2) By managing process parameters
3) By proper choice of plasma nitriding method
4) By carrying different manufacturing methods carefully
5) By Use of Suitable Analysis and Defect Finding Techniques
1) By Changing Material

Basically material used for piston rod of compressor is AISI 4340 steel. It is steel which harder material to machine is and it is best material only if not going to heat treatment. Also cutting speed is less due to harder material. But by using this material porosity defect is ocurred on material after plasma nitriding. So testing on AISI4140 is carried out side by side. Material properties and chemical composition is discussed in following table.

Table 2: Material Composition Comparison between AISI 4140 & AISI 4340 Steel

AISI	C	Si	Mn	P	S	Cr	Mo	Ni
4340	0.38 - 0.43	0.15 - 0.35	0.6 - 0.8	0 - 0.035	0 - 0.040	0.7 - 0.9	0.2 - 0.3	1.7 - 2.0
4140	0.38 - 0.43	0.15 - 0.35	0.75 - 1.0	0 - 0.035	0 - 0.040	0.8 - 1.1	0.15 - 0.25	AB

Table 3: Material Properties Comparison between AISI 4140 & AISI 4340 Steel

AISI	Tensile Strength(Mpa)	Yield Strength (Mpa)	Elongation (%)	Reduction in Area (%)	Hardness(HB)	Impact Strength (J)	Thermal Expansion (106/ºC)	Thermal Conductivity (W/mK)
4340	744.6	472.3	22	49.9	197	51.1	11.5	41.5
4140	655	417.1	16-26	56.9	217	54.5	12.3	42.7

B. AISI 4340

This is nickel-chromium-molybdenum alloy steel which have very high strength. It is sought after for its toughness and for being used as a steel that will be highly stressed. It is used in variety of industries for different applications including the automobile, aerospace and tooling industries. AISI 4340 contains 1.65-2% Nickel. This contributes to substantial differences in hardenability and fracture toughness and also has a positive effect on distortion during quenching and corrosion resistance.

C. AISI 4140

It is low alloy steel contains high amount of chromium. It has good machinability, ductility, weld ability and strength characteristics. It is used for many different industries including automobile, aerospace and machining industries. In 4140 steel Nickel is not present. It is ideal material & use by every industry as a base material. AISI 4140 is less harder as compare to 4340 steel. So it can be machined easily. This material require less cutting speed than 4340 steel.

Due to slight variation in material composition, difference in yield strength is attributed in heat treatment process. So there is variation found in result of this Martials. The material composition may get vary with minor percentage for different manufacturers and vendors. So proper manufacturer selection is necessary. AISI 4340 & 4140 are both popular steel grades which mostly preferred by all industries. Both of these alloys can be used for many of the same applications. Since plasma nitriding doesn't require very high level of fracture toughness at low temprature that 4340 offers. So 4340 is replaced with AISI 4140 steel.

Also due to higher surface hardness caused by the additional alloy elements causes lower tendency to adhere or wear partner & in increased abrasion resistance. Increased surface hardness material causes a higher risk of cracking during mechanical stressing. AISI 4340 have higher surface hardness value than 4140 so it have high risk of cracking. Hence material 4340 is replaced by AISI 4140 steel.

2) By Managing Process Parameters

A number of operating process parameters must be adhered to and controlled in order to successfully carry out the nitriding process. Most of these parameters can be controlled with relatively simple instrumentation and methods. There are many factors that can cause porosity on piston rod after nitriding. Factors are as follows –

1) Proper metallographic preparation before operation

Before Nitriding, the components have to be thoroughly cleaned and degreased. Any surface contamination from grinding particles, oil or metal chips will result in an uneven formation of the nitrided layer. This can cause cracks in the coating which leads to flaking and corrosion. After cleaning, the parts are dried and preheated and then transferred to the actual Nitriding environment. To avoid damage to the nitride layer, it is recommended that sectioning is carried out carefully on a cut-off machine with water cooling, suitable for metallographic purposes.

2) Pre Heat Treatment Process

Generally most of times defect is caused in nitriding due to Pre Heat Treatment process. Pre Heat treatment is required for uniformity of hardness layer before nitriding process. Pre Heat treatment includes process like Oil Quenching, cleaning, tempering, and austempering before actual process.

3) Variation in design of nitriding furnace

Design of Nitriding furnace also effects on white layer formation and reduction in defects. Furnace must be properly design so that it can withstand nitriding temprature range.

4) Plasma Nitriding temprature

Proper plasma nitriding temperature must be maintained to avoid excessive while layer formation on material. Temperature required for plasma nitriding is in between 400 to 600 degree celsius. Plasma nitriding process require less temperature than other hardening process.

5) Deformation of Nitrogen

Deformability of nitrided component not only depends on thin, hard nitride layer but also on chemical composition and structure of base material. The more homogenous & fine-grained structure is, better nitriding result. Generally, tempered initial state (QT) is preferred over soft annealed state (A).

Nitrogen is transferred from surrounding medium in following steps:-

1) Adsorption of nitrogen atoms on the surface of the component
2) Absorption of nitrogen atoms by the component surface
3) Diffusion of the nitrogen atoms along the grain boundaries and within the grains

Nitrides form around seed points on surface of component (grain boundaries and nodes at which several grains meet). As nitrogen concentration and nitriding time increase, nitrides grow deeper and expand laterally into grains until a closed layer has been formed. Along with nitride forming alloy elements, nitrides form and disperse sub microscopically in matrix.

The transition from hardness of diffusion zone to core hardness of base material is fluid, which, unlike surface layers, reduces risk of chipping during mechanical stressing. Nitride layers are also heat resistant up to approx. 550°C.

6) Hydrogen activation on surface

The hydrogen gas is filled in the furnace in which metal is placed to carry out nitration process. The hydrogen gas in the furnace activates the surface of the metal on which nitration is carried out. It does not interfere in the process of nitration.

7) Uniform distribution of metal on piston rod surface

Uniformity must be maintained for deposition of material on surface. By uniform distribution of material proper white layer is form on rod material. This uniformity is maintained by different parameters like temparature, Nitrogen deposition rate, and Proper process time.

8) Nitrogen to Hydrogen deposition ratio

White layer formation to increase hardness depends mainly on Nitrogen to Hydrogen deposition ratio. Nitrogen particle is bombarded on piston pod with specific velocity. If this particles is not bombarded in proper ratio then, due to this chipping defect is occurred on white layer of nitrided surface. Hydrogen to Nitrogen gas deposition ratio must be 1:3. Nitrogen must be three times greater than Hydrogen.

9) Maintaining proper process time

It is one of the important point in Plasma Nitriding process. Deposition of White layer on material depends mainly on proper process time maintenance. If process time taken is more than required, then there is possibility of Scaling formation. More process time than required increases causes more brittleness in in material. So proper process time must be maintained.

The required case depth is determined by application of the nitrided component and can be regulated through the Nitriding temperature and time.

10) Effect of Hardness

Higher surface hardness which is caused by the additional alloy elements causes lower tendency to adhere to a wear partner & in increased abrasion resistance.

Increasing surface hardness creates higher risk of cracking during mechanical stressing. Hardness value increases as temprature increases.

11) Proper tempering temprature

As tempering temperature increases, amount of Cr and Mo carbides increases as well. This reduces the precipitation of nitrides and results in a lower increase in hardness. The nitriding temperature should be below tempering temperature in order to keep the core hardness from decreasing.

12) Depth of Nitriding hardness

The depth of nitriding hardness is a characteristic value for thickness of nitride layer. It describes vertical distance from surface to point at which hardness is still 50HV higher than core hardness.

To minimize or avoid porosity effect above factors must be considered. It is necessary to understand this factors briefly before implementing it.

4) Proper choice of plasma nitriding method

There are 2 methods available for plasma nitriding; Active Screen Plasma Nitriding (ASPN) & Direct Current Plasma Nitriding (DCPN).Proper choice between these 2 methods is necessary to get defect free workpiece. There are many advantages of both methods. ASPN is a new industrial solution that have all the advantages of DCPN but does not have its inconveniences. Direct current plasma nitriding have many limitations that ASPN doesn't have.

DCPN process has limitations which are mainly based on the effects resulting from the formation of an electrical field. This limitations like hollow cathode effect, arking, edge effect, bad temperature control and uniformity ocurred in DCPN.So proper selection between this two methods is necessary while plasma nitriding. Due to more advantages and less possibility of defects Active Screen Plasma Nitrding is mostly preferred by industries.

5) By Carrying Different Manufacturing Process Carefully

Manufacture processes of piston rod like grinding, centering, turning, thread rolling must be carry out carefully. There are more chances of defects in grinding process. So it must be done carefully. After manufacturing rod all properties like tensile strength, hardness must be check before nitriding. Pre heat treatments like tempering, oil quenching, cleaning with Argon gas are also required before plasma nitriding process. This processes must be done carefully before nitriding.

6) By Use of Suitable Analysis and Defect Finding Techniques

Several techniques were applied in this study in order to investigate the effect of nitridation on the oxidation behavior at elevated temperatures and the related phase and microstructure development in the AISI 4340

Optical microscopes were mainly used for preliminary inspections of samples before and after oxidation. It was observed that microstructure of material was revealed by etching effect of plasma during nitriding. The stereomicroscope gives a good overview of specimens and allows identification of most interesting regions for subsequent analyses of oxidized samples. Stereomicroscope was also used during the process of sample preparation to check polishing quality on the surface of samples before exposures.

V. CONCLUSION

Plasma Nitriding is a very well established heat treatment method for increasing the wear, fatigue and corrosion resistance of most steels surfaces.

From investigation it has been found that by changing material of piston rod defects like porosity gets reduced. Due to hard AISI 4340 material nitriding dissociation gets many problems, uniformity is not maintained. Due to higher surface hardness caused by the additional alloy elements causes lower tendency to adhere or wear partner & in increased abrasion resistance. Increased surface hardness material causes a higher risk of cracking during mechanical stressing. So by changing material from AISI 4340 to AISI 4140 porosity defect gets reduced.

Material yield strength is also one of the important parameter. Yield strength may vary by supplier to supplier. Difference in yield strength was attributed mainly to the heat treatment providers rather than the metal suppliers and composition. So material with proper yield strength must be selected.

Also by managing process parameters, nitriding process can be successfully carried out and defect will get reduced. Parameters like Pre heat treatments, Nitriding temprature, and Nitrogen dissociation, Nitrogen to hydrogen dissociation ratio, Hydrogen activation, and Maintaining proper process time must be controlled.

The issue of environmental degradation, pollution, and global warming has become a very serious problem to the entire world. This calls for the use of technology that is environmentally friendly to cut-down on the harm already done to the earth. ASPN is one of such technology, after analyzing it following conclusion we get ASPN may replace any other plasma assisted nitriding equipment, it is economical & ecofriendly process. Also ASPN makes nitriding of steel easier and more efficient. This process is suitable for small as well as bulk materials. So it is mostly preferred.

Also DCPN process can be used by making certain modifications. In order to avoid problems attributed with DC nitriding, many efforts have been made over past few years to develop high productive plasma nitriding methods. The same type of complex nitrided layer can be produced by numerous nitriding methods, plasma source ion nitriding, anodic nitriding, laser nitriding, cyclic plasma nitriding catalyzed by metals, cathodic cage plasma nitriding or nitrogen ion-beam implantation combined with pulsed plasma nitriding can be used.

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