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Improvement of Wear Resistance in Engine Cylinder Liners Using Gas Nitriding

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Abstract- The project is aimed at improving the wear resistance of the cylinder liner which is used in internal combustion engine and many other applications.Gas nitriding process has been used for fullfillment of project objectives.The study has been conducted to observe the change in hardness before and after gas nitriding of cylinder liners which inturn impact on wear resistance of cylinder liners.

Index terms :**Nitriding,Gas nitriding,Cylinder liner, Wear resistance, Hardness, Internal combustion engine.**

I. INTRODUCTION

In today's automotive field cylinder liners plays a crucial role because they are integrated part of engine block.The cylinder liner is exposed to high temperatures while operating with in the internal combustion engine. During the reciprocating motion of the piston, the piston will come in contact with the inner surface of the cylinder liner. Hence properties such as hardness and wear resistance of cylinder liner plays a crucial role in determining efficient functioning of the cylinder liner.Hardness and wear resistance properties can be improved by using techniques such as carburizing, nitriding etc.

II. HISTORY

In the early years of the 20th century, Adolph Machlet recognized that the 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 soon 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.

In Germany, a parallel research program was under way headed by Dr.Adolph Fry in 1906. Like Machlet, Fry recognized that nitrogen was very soluble in iron at an elevated temperature. He also recognized very early in his work that alloying elements strongly influenced metallurgical and performance results. He used a technique similar to that of Machlet, where the nitrogen source had to be cracked by heat to liberate nitrogen for reaction and diffusion.Like Machlet, Fry used ammonia as the source gas, but he did not use hydrogen as a dilutant gas. Thus was developed the single-stage gas nitriding process as it is known today.Fry then investigated the effects of alloying elements on surface hardness.He discovered that the 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.

III. NITRIDING

Nitrding is a thermochemical process in which the surface of the ferrous metal is added with nitrogen inorder to improve wear resistance of the components. The diffusion process is based on the soloubility of nitrogen in iron. As nitriding is one of the important surface hardening technique this was being used in the manufacturing of aircraft, bearings, textile machinery and automotive components manufacturing such as valves, camshafts and piston rods etc.

IV. WHY NITRIDING

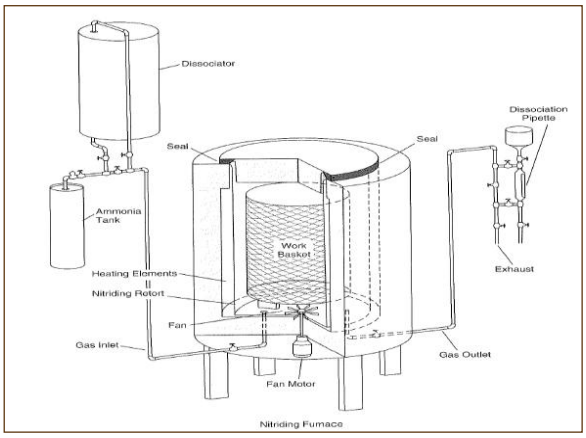
Nitriding process does not require a phase change i.e steel remains in the same ferrite phase during the complete process. While in the traditional process there will be a phase change from ferrite to austentite and austentite to martensite.As free cooling takes place in the nitriding process quenching is not required.Nitriding improves the fatigue life, provides anti-galling properties and high surface hardness. Nitriding process takes place comparitively at low temperatures when compared to other case hardening techniques and it is also cost effective.

V. TYPES OF NITRIDING

- Gas nitriding
- Salt bath nitriding
- Plasma nitriding

VI.GAS NITRIDING

Gas nitriding is a type of nitriding in which the nitriding surface to be formed on the surface of the component by using the nitrogen obtained from the diffusion of ammonia.This process will take place inside a furnace by maintaining the required conditions.The schematic diagram of gas nitriding will be as follows:



The chemical reactions that takes place during the process of gas nitriding will be as follows:

$$2NH_3 \Longrightarrow N_2 + 3H_2$$

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The ammonia gas is provided to the furnace in which the cylinder liner is being nitrided will undergo the above reaction at the temperatures of 500^0 c to 650^0 c maintained in the furnace which will result in the dissociation of ammonia resulting in nascent nitrogen.The nascent nitrogen will react with the ferric content of the cylinder liner forming a white layer on the surface of the cylinder liner due to formation of Fe_3N and Fe_4N. The process is carried out as two distinct events. The first portion of the cycle is accomplished as a normal nitriding cycle at a temperature of about 500 °C (930 °F) with 15 to 30% dissociation of the ammonia (i.e., an atmosphere that contains 70 to 85% ammonia). This will produce the nitrogen-rich compound at the surface. Once the cycle is complete, the furnace temperature is increased to approximately 560 °C (1030 °F), with gas dissociation increased to 75 to 85% (i.e., an atmosphere that contains 15 to 25% ammonia). The two-stage process is used to reduce formation of the compound zone only. There are some process parameters involved in the gas nitriding process which need to be observed inorder to produce a nitride layer on cylinder liner as per the requirements.

Process parameters for gas nitriding include:

- Furnace temperature
- Time
- Gas flow
- Gas activity control
- Process chamber maintenance

The process control factors are those elements that will ensure a controlled process and acceptable results:

- The total surface area of cylinder liner to be nitrided.
- Process pressure to be maintained inside the sealed process chamber.
- Gas delivery pressure system into the sealed process chamber in the furnace.
- Exhaust gas system from the sealed process chamber.
- Control of the preheat treatment procedure prior to nitriding, including stress relief and prehardening and tempering.
- Quality and integrity of the steel surface precleaning prior to nitriding.
- Consistent steel chemistry.

The cylinder liner that to be nitrided should not undergo quenching or any other heat treatment process which may result in phase change. The cylinder liner should be completely washed by an aqeous alkaline detergent or an equivalent.It should be completely cleaned to avoid all types of contaminants so that there will be no effect on nitriding layer. By taking all the prerequisites into consideration , by using the process parameters and process control factors we will perform the process of nitriding on the cylinder liners.

Advantages :

• The nitriding process is relatively a low temperature process compared to other techniques such as carburization, carbonitriding etc.

• No phase change during the process, no molecular size change.

• Improves fatigue strength,wear resistance and provides anti-galling properties.

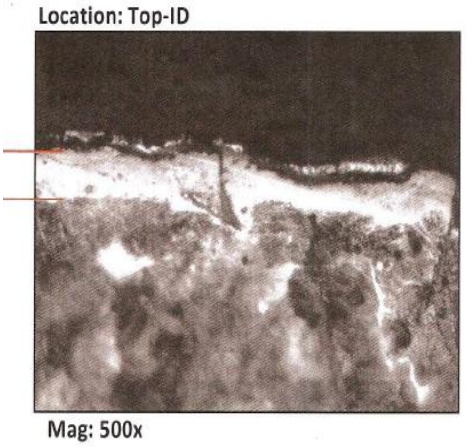
Limitations :

• Nitriding process can not be applied to the stainless steels.

• Nitriding process results in the increase in volume of the component.

VII. RESULTS

The nitriding process will cause a change in the microstructure of cylinder liner. The microstructures of the cylinder liner after nitriding process on both inner diameter and outerdiameter of liner at top and bottom were shown below:



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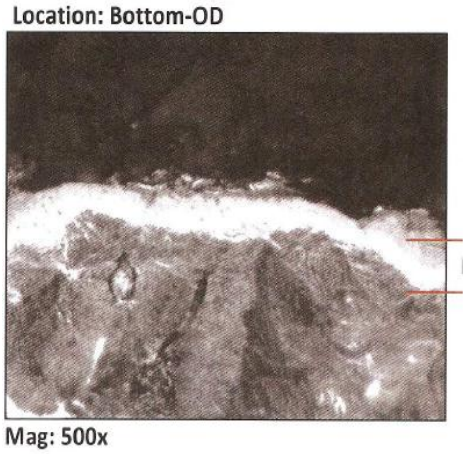

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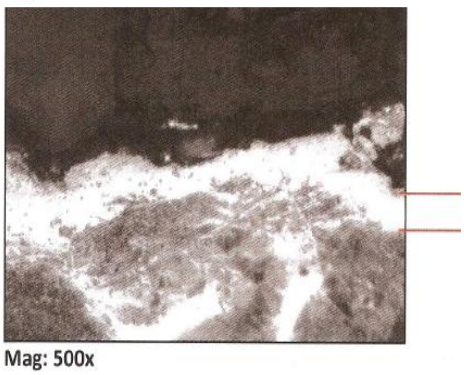

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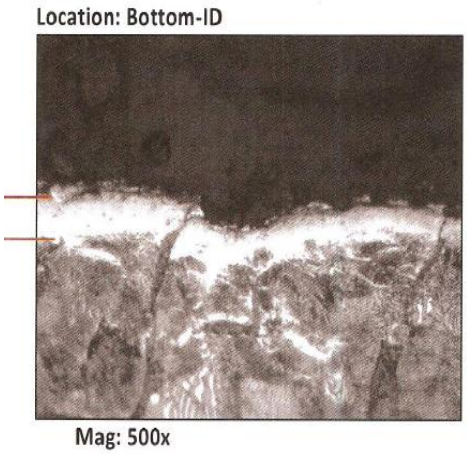

The side indication marks in images indicate the white nitriding layer thickness.

The image shows a nitrided cylinder liner.The nitrided cylinder liner will develop a white layer on its surface and the hardness values of cylinder liner before and after nitriding will be as follows:

BEFORE NITRIDING	
Micro vickers hardness test	
Location	Observation in $HV_{50\ gm}$
Top OD	560.3
Top ID	516.7
Bottom OD	597.6
Bottom ID	576.6

Nitriding layer thickness measurement by microscopic method	
Location	Microns
Top OD	12 – 13
Top ID	12 – 13
Bottom OD	10 – 11
Bottom ID	10 – 12

Although there is an increase in the thickness due to nitriding layer around 10-12 microns, the cylinder liner has been provided with extraordinary improvements.The hardness values of the cylinder liner were increased by about forty percent due to the nitriding process which results in very good improvement of wear resistance for liners.This resulted in a huge improvement in the life of cylinder liners and it was a success.

VIII. DISCUSSION

In todays competitive automotive world cylinder liners provided with good hardness and wear resistance properties were best choosen to provide customer satisfaction.For the cylinder liner manufacturing industries to remain competitive in the present market situation implementation of nitriding process will be best suited in order to increase the life of the liners which they produce to satisfy customer requirements.It not only provides cylinder liners with good wear resistance but also improves the standards of customer satisfaction and also acts as an important heat treatment process compared to other traditional techniques.Nitriding is now widely discussed and many cylinder liner manufacturing industries started apllying it across the globe.

IX. CONCLUSION

From the above observations it can be concluded that nitriding process has been carried out across globe in many manufacturing industries and still a lot of research is going on.But as nitriding acts as a key process in improving wear resistance properties it has been applied in several cylinder liner and other automotive industries.Further research has to take place in order to implement the nitriding process in other industries for improving properties.So a good deal of research is available if provided with proper technical and financial feasibilities.Succesful nitriding implementation industries indicates that it require good financial and technical support to fully implement the system.

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