Mechanical and Metallurgical Behaviours of Nitrided Aircraft Shaft

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Abstract - *Nitriding is a thermo-chemical process by which the surface of a ferrous metal is enriched with nitrogen to improve the wear resistance along with anti galling properties, high surface hardness, improved fatigue resistance, better creep resistance and enhanced corrosion resistance of the components. The Nitriding technology shows a clear orientation towards future developments. Hence, it ideally satisfies current and future industrial demands for economical and efficient solutions to the treatment of surfaces. It is also an answer to social demands for improved environmental protection. So that, it has act as a major role in manufacturing of automotives, railways, aircraft and aerospace components such as engine assembly parts, tappets, valves, bearings, shafts, Piston Pins, Spacers, rods, Screws, Washers, Nuts propeller control and power control Systems, etc., In the present, we are interested to study the mechanical and metallurgical behaviours of nitrided aircraft shaft, which is newly designed by the theoretical modeling of Solid Works Simulation Xpress Study and the same practically developed by using of Plain Carbon Steel i.e. AMS 5069 /AISI 1018 and also we would like to enhance their Mechanical Properties with help of Nitrding. After Nitriding, the qualitative analysis was done by Rockwell Hardness Testing, Microstructure Examinations, Case depth and Compound Zone Determinations, etc., The obtained results are compared and conclude whether the chosen material is suitable for producing the Aircraft Shaft by the way of economy.*

Key Words - Nitriding for AISI 1018 Steel, Aircraft Shaft, Corrosion Resistance, Nitriting in Aircraft, ect.,

1.0 INTRODUCTION:

The corrosion of metals is a destructive process regarding to the basic modern engineering constructional material with a great importance for the nowadays industry and in many cases represents an enormous economic loss. Therefore, it is not a surprise that the research on the corrosion and corrosion protection of metallic materials is developed on a large scale in different directions and a wide range of engineering decisions. For all that, the improvement of corrosion behaviour of metals and alloys still stays as one of the most important engineering problems in the area of materials application and it is one of the fundamental parts of modern surface engineering. Special attention is usually focused on the corrosion behaviour of steels as the most commonly used engineering material, because of the limited corrosion resistance for many basic types of these alloys. In more cases they are selected not for their corrosion resistance and important properties are strength, easy fabrication and cost, but there are a lot of exploitation conditions requiring high corrosion resistance. For such a purpose is developed the special group of stainless steels which covers with a high level of certainty these requirements. The stainless steels have an excellent corrosion resistance, but it is not always attended with high strength, hardness and wear resistance. Together with the higher price of the high-alloy steels these are the main restriction for many applications and open up a wide field of opportunities for the surface modification as a method for combination of corrosion resistance along with high strength, hardness and wear resistance.
Surface modification in a wider sense includes all types of surface treatments and coatings that result in change in composition and microstructure of the surface layer. There are different methods for modifying the surfaces of structural alloys, dictated by the performance requirements of the alloy in its service environment. One of the approaches, traditional for the steels, is to modify the surface region of engineering alloys via diffusion of different elements and forming a layer with determinate chemical composition, microstructure and properties. These are the commonly used in practice methods for thermochemical treatment of metals which extended with the methods for physical vapor deposition and chemical vapor deposition form the basic modern techniques for surface engineering regarding to metals. [1].
Nitriding is one of the surface diffusion engineering processes, It enhance surface hardness of the Metals in which Nitrogen is allowed to diffuse into the surface layer by heating the metal in contact with the Nitrogenous medium in the temperature range of 350^0C to 600^0c. This process can effectively give high surface hardness, wear resistance along with anti galling properties, improved fatigue resistance, better creep resistance and enhanced corrosion resistance (except in the case of stainless steels). Nitriding is carried out at temperature much less than the carburizing and hardening temperatures (below the lower critical temperature) produces negligible distortion in the component [2].Nitriding is mainly used in aircraft industry because it enhance high surface hardness, wear resistance along with anti galling properties, improved fatigue resistance, better creep resistance and corrosion resistance with economy and pollution free [3]. So that, there are enormous allied components such as Aircraft valves, Aircraft camshafts and Aircraft Pistons, Rods, Spacer, Diaphragms, Shafts, Pins, Nuts & Bolts, Screw, etc., and many precision components are nitrided. Other applications are cutting tools or large forming dies, Cast iron parts, such as pump and gear houses, can also be nitrided.

2.0 EXPERIMENTAL METHODOLOGY

2.1 Solid Works Simulation Xpress Study

We made a simulation model before making of real part by using of Solid Work Xpress Study and developed new model for suitable design and also determined the effects of force and pressure of the aircraft shaft assemblies by theoretically.

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2.2 Chemistry of Chosen Steel

Before Nitriding the chemical composition (grade confirmations) of the chosen steel material AMS 5069/AISI 1018, size of ∅ 32mm X 200mm was studied by using wet chemistry method [4,5,6, 7 & 8] and the percentage of assigning elements are shown in the Table 2.2.

Table: 2.2 Chemistry of AISI 1018 Grade Steel

∅ 32mm,	(%) Percentage of Assign. Elements				
	C	Mn	Si	P	S
Spec. min.-max	0.15-0.20	0.60-0.90	0.40 max	0.050 Max	0.050 Max.
Obtained	0.179	0.67	0.303	0.027	0.026

2.3 Nitriding Process

The Nitriding process using Liquid Nitriding or gas was developed in the early 20th century in Germany and the United States. The development of ion or plasma Nitriding started in the 1930s but was not commercially used until the 1970s.All three Nitriding methods have advantages and the selection of a particular method depends on the specific application of the nitrided component [2].

In this present study we are used Gas Nitriding Process due to the availability and economy, the process techniques as follows, the Gas Nitriding is takes place in a sealed, bell-type Nitriding furnace which provides good gas circulation. The process is mainly controlled by the degree of dissociation of ammonia. The ammonia gas reacts at 500-520°C [9] with the steel surface and decomposes, thereby releasing nascent nitrogen which diffuses into the steel surface. As gas Nitriding uses a lower temperature, process times are 40- 80 hrs. During the process of Nitriding the Nitrogen content reaches a value about 5.5% up to a depth of 16 – 50 μm (Microns) and then gradually decreases with distance from surface this surface layer containing high N_2 content results in the formation of ∊ and γ′ – Nitrides in the interior contains a dispersion of γ′– Nitride in α– phase. These two layers are called the compound layer and diffusion layer respectively. The formation and properties of the compound layer and diffusion zone are similar to those produced by salt bath Nitriding. However, the thickness of the compound zone can be more accurately controlled or even completely suppressed with gas Nitriding [10,11].

2.4 Mechanical & Metallurgical Testing

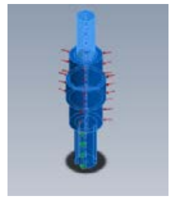
Surface Hardness of the nitrided Component i.e. AISI 1018 Aircraft Shaft samples were studied by Rockwell Hardness Tester (HRC-Scale, Make: FIE, Model: RAB 250, Load 150Kg) & Micro Vickers Hardness Tester (HV1 Scale, Make: Mitotoyo, Model: MVK E3). Metallographic study is the imaging of topographical or micro structural features on prepared surfaces of materials [12, 13]. The structures studied by metallography are indicative of the properties and performance of materials studied. As the evaluation of the Nitriding diffusion is carried out with 100 X magnifications [14] by Matascope make Metallurgical Microscope (Model T1600).

3.0 Results and Discussion

3.1 Results of Solid Works Simulation Study

By using the Solid Works Simulation Models (Shown in Fig.3.1, 3.2 & 3.3) for the AISI 1018 aircraft shaft had been undergone four studies Viz., displacement, deformation and FOS and the obtained studies as follows

3.1.1. The Volumetric Properties



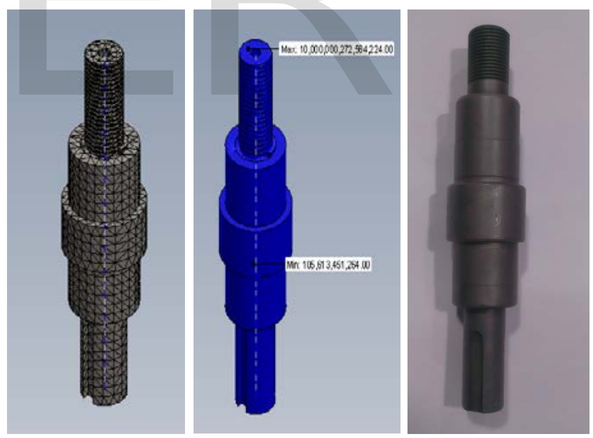
Mass	:0.565486 kg,
Volume	:7.15805e-005 m^3
Density	:7900 kg/m^3
Weight	:5.54176 N

Fig.3.1.1 Simulation Model Volumetric Properties

3.1.2 The Mechanical Properties

Name	: **AISI 1018**
Model type	: **Linear Elastic Isotropic**
Default failure criterion	: **Max von Mises Stress**
Yield strength	: **3.51571e+008 N/m^2**
Tensile strength	: **4.20507e+008 N/m^2**
Displacement	: 3.39 e^{-13}mm
Deformation	: Fig.3.3 shown below.
F.O.S	: 1.0 e16 No unit

(Note: the obtained results as default properties of in-build for the material of AISI 1018)



(a) *(b)* *(c)*

Fig.3.1.2 (a) Von Mises Stress Solid Mesh
Fig.3.1.2 (b) Factor of Safety (FOS)
Fig.3.1.2 (c) Real Nitrided AISI 1018 Aircraft shaft

3.2 Mechanical & Metallurgical Testing

The Mechanical and metallurgical behaviors the Nitrided Aircraft Shafts were carried out by Rockwell and Vickers Hardness Testing, Case depth, Compound Zone (Case Depth and White Layer) determination and Micro examinations in the Metallurgical Microscopes at Magnifications 100X.The Microstructure shown in Fig 3.3 The Obtained results are given in table 3.3 below.

Table: 3.3 Mechanical & Metallurgical behaviors of Nitrided Aircraft Shafts-Test Results

Surfaces Hardness		**Core Hardness (HRC)**	**Case Depth (mm)**	**White Layer in (µm)**
150 kg (HRC)	**1 Kg (HV1Kg)**			
54	754	31-32	0.7	22-25

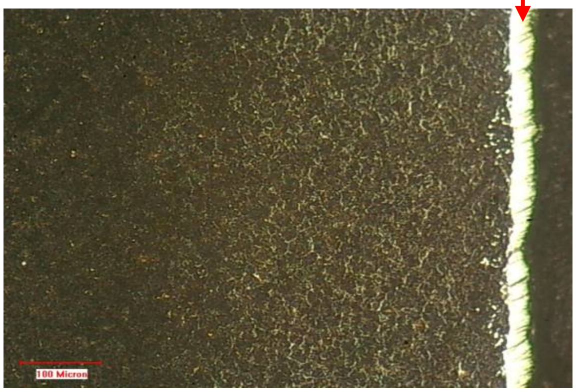


Fig.3.3 (a) Case: Microstructure of Nitrided AISI 1018 Aircraft Shaft Magnification@ 100X-3% Nital. (Tempered Martensite).

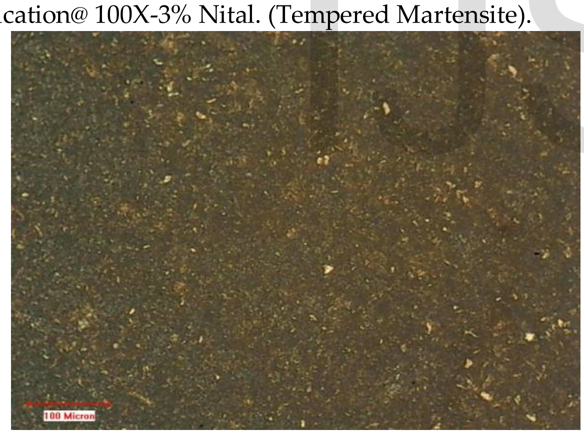


Fig.3.3 (b) Core: Microstructure of Nitrided AISI 1018 Aircraft Shaft Magnification@ 100X-3% Nital. (Reveals Tempered Martensite).

From the behaviours of Mechanical and Metallurgical properties of the final Part of this investigation i.e. Nitrided Aircraft Shafts and the effectiveness of the Nitriding, we observed surface hardness of the AISI Aircraft shaft is 754 HV_{1Kg} and the case depth is 0.7 mm obtained, similarly the formation of (nitrogen diffusion Layer) white layer is around 22-25 microns and also the obtained microstructure is tempered martensite. All the above obtained results are authentically says the improvement of wear and tear resistance, Fatigue resistance, anti-galling properties and enhanced corrosion properties of the newly designed nitride Aircraft Shafts by the Nitriding Process.

The obtained surface, Core hardness values and Micro structural features of Gas Nitrided AISI 1018 Aircraft Shaft is found satisfactory with their macro properties [2] and these are gives an idea to made Aircraft shaft by AISI 1018 material for this type of specialized specific requirements and Applications.

4.0 Summary & Conclusions

From the Solid Work Simulation Xpress Study, Indeed, these Aircraft shafts may operate under severe conditions such as high-speed, starved or contaminated lubrication. Furthermore, their design may be complex, integrating multiple functions, and requires thin sections for weight reduction. It has evidenced to the Deep Nitriding of AISI 1018 steel offers a better compromise than classical high Precision shaft steels (through hardened or carburized) to meet these requirements. The core material has excellent toughness for structural functions and high rotational speeds. Due to the semi-coherent precipitation of nano-metric nitrides, the nitrided layer features high hardness, high compressive residual stresses and superior rolling contact properties. The Nitriding technology makes easier the production of parts with complex shapes, with a limited amount of finish grinding because of the limited distortions resulting from low temperature cycle. The manufacturing process is under control and properties show small dispersion.

From the overall study, we conclude that the Nitrided Aircraft Shaft by AISI 1018/AMS 5069 grade Steel Material is achieved very good mechanical and metallurgical properties. The deep Nitriding process applied to AISI 1018 (AMS 5069) steel solves in a convenient way the difficult compromise concerning the incompatible properties required for Aircraft shafts. All these features make the deep nitride AISI 1018 an excellent solution for high reliability and safety Aircraft components for consideration of economy.

References

1. ASM International, *Surface Engineering, ASM Hand Book, ASM International, Vol.5, (2009).*
2. "P.Kuppuraj*, S.Gunasekaran, P.Puliarasan",, *Plasma (Ion) Nitriding of Low Alloy Steel (EN19 grade) and Investigation of Its Physico-Mechanical Properties, International Journal of Science, Technology and Humanities 1 (2014) 93-98.*
3. David Pye, *Practical Nitriding and Ferritic Nitro Carburising, ASM International Publication, (2003).*
4. *Determination of Carbon Percentage in Plain and Low Alloy Steels, IS 228, Part-1,(2008)*
5. *Determination of Manganese Percentage in Plain and Low Alloy Steels, IS 228, Part-2, (2008).*
6. *Determination of Phosphorus Percentage in Plain and Low Alloy Steels, IS 228, Part-3, (2008)*
7. *Determination of Silica Percentage in Plain and Low Alloy Steels, IS 228, Part-8,(2008)*
8. *Determination of Sulphur Percentage in Plain and Low Alloy Steels, IS 228, Part-9 (2008)*
9. L. F. zagonal, C. A. Figueroa, R. DroppaJr, F.Alvarez *Influence of the process temperature on the steel microstructure and hardening in pulsed plasma nitriding, Journal of Surface and Coating technology, ,Vol. -201.Issue 1-2,12.Sep.(2006).*
10. V.Partharthy, *Nitriding Is the Best Surface Hardening Technology For Tools & Dies, Technical Paper, ASM Chennai Chapter,(2012).*
11. *Heat Treating, ASM Hand Book, Vol. 4, (2009).*
12. *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials, ASTM E18-15(2015).*

13. *Standard Test Method for Vickers Hardness of Metallic Materials, IS 1501, Part-2,(2013).*
14. *Metallographic and Microstructures, ASM hand Book, Vol.9, ASM International (2009).*