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Material Processing - 300 M Steel Surface Enhancement of Landing Gear by Shot Peening Method and Reducing Corrosion Fatigue

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Abstract: Today's Landing Gears in Aircrafts are mostly made using materials like Titanium 6-4 Alloys (Ti6Al4V),, AF1410, 300M, 4340, Ti10-2-3(Ti10V2Fe 2Al) , Ti 5-5-5-3(Ti 5 Va 5Mo 5Al 3Cr) etc. But among these, 300MSteel is the widely used material and accounts for 60% production. Thus the 300 M Steel is Extremely Preferred due to its Cost Effectively. It also posses very high Physical Properties like High Fracture Toughness and less Corrosion Fatigue. Landing Gear Supports the Entire force acting on the wheels during landing and takeoff of aircraft. Further issues like, catastrophic scenario of a U.S aircraft" Flight 173" crash in 1978 due to corrosion failure in landing gear material increased the urge of improvement in its physical properties by reducing its corrosion Fatigue properties.

Keywords: 300 M Steel, Shot Peening, Surface Enhancement, Corrosion Fatigue, Fracture Toughness

1. INTRODUCTION

THIS paper discuss the improvement of damage tolerance (i.e.) Corrosion Fatigue of 300 M steel by Shot Peening Method."MATERIAL PROCESSING" is typically considered to be a series of operation that converts a raw material into finished industrial products.

Landing Gear is the under carriage of an Aircraft which supports the aircraft during takeoff, landing and taxing. The landing gear center beam acts as the main airframe and the impact loads depends on the airframe. Thus the material used is indispensable in landing gear. Numerous amount of designs and methods of landing gear has evolved over a period of time, the ultimate goal is to achieve the final destination of shock absorbing also to sustain the impact in a form of cyclic stress and reduce the space for catastrophic scenarios. Extreme efforts , enormous number of researches have taken place over a period of time to curb all the lacking features for the cause of accidents. Accidents include the military as well as the civilian planes and the accidents to occur all over the six continents.

Flying is generally a safe and fastest method of transportation, but accidents always happen through human error or mechanical failure. Over the last few decades there have been many fatal aircraft accidents per year worldwide.

In recent years progress and development in science and technology have made dramatic contributions to human society. This trend is in no means an indication of carelessness on the part of a individual rather it can be considered as the safety measures in the past has reached its saturation limit of effectiveness .Thus improvement in the mechanical failures becomes a back bone of safety measures.

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2. LANDING GEAR MATERIALS

A large amount of force is applied through the undercarriage as it touches the ground during landing process, to prevent damage to the structure, the shock must be absorbed and dissipated by the undercarriage.

Material composition is a efficacy of the above process.

Graphite epoxy is one of the widely used composite materials for aircraft components and structure. These are strong fibers embedded in a resin. However the tooling cost and complexity is increased compared to other materials.

Titanium is about as strong as steel and weighs less, though it is not as light as aluminum. It holds better strength in high temperatures and resists corrosion better than steel or aluminum. Even if Titanium is expensive these characteristics have led to greater advancement in modern aircraft.

Aluminum is also highly preferred due to light weight and its strength. But Aluminum alloys lose their strength at high temperatures.

300M STEEL can be made four times stronger and three times stiffer than aluminum but still it becomes three times heavier than aluminum. It is specifically used for components like landing gear where strength and hardness are especially important. It holds its strength better at higher temperatures better than aluminum

300M is a low steel alloy, vacuum melted, steel of very high strength. Essentially it is a modified AISI 4340 steel with silicon, vanadium and slightly greater carbon and molybdenum content than 4340. 300M has a very good combination of strength (1900-2100 MPA after final heat treatment), toughness, fatigue strength and good ductility. 300M is a through hardening alloy. 3ooM is a deep hardening steel with excellent torque properties, high fatigue and creep characteristics, and maintains its strength at moderately high temperatures.

A Process that ameliorates the fatigue life of a material by providing a surface layer of compressive residual stress that expands the life of fatigue crack initiation and resists crack propagation. Temperature plays a vulnerable role as the material should not relax at the operating temperature so as to retain the advantages of surface enhancement. So a appropriate cold working process is in demand.

3. COLD WORKING PROCESS

1. Shot Peening
2. Gravity Peening
3. Laser Shock Peening
4. Low Plasticity Burnishing

All mechanical surface enhancement methods create a layer of compressive residual stress by tensile deformation but differ in magnitude and surface enhancement. The depth of the Peening and the degree of the Peening process depends upon the intensity of the process.

The process is strengthening of metal by plastic deformation. The Dislocation of molecules in the structure causes the actual strengthening. Generally, Alloys are not exposed to heat treatment as the regeneration of molecules take place. Hence the strengthening of alloys is a work hardening process. Cold working process is executed below the recrystallization temperature of the respective material.

During surface enhancement there is a minimum amount of plastic deformation will take place, along with minimum elastic reversible deformation in a combination which is highly applicable on steels and its alloys. These basic properties will strictly follow Hooke's Law.

Cold working processes are of primacy. The contamination problems are severely reduced as they have superior dimensional control. Due to this Directional properties can be imparted into the metal. It has a better reproducibility and interchangeability.

All engineering materials have certain mechanical properties. The most important of these are as follows that will be tested on basic standard procedure before that is subjected to the shot Peening process. The main tests are those for tensile and compressive stresses.

1. Strength is the ability of the material to withstand large forces without breaking. The forces may be tensile, compressive or shear. A strong metal can withstand larger forces than weak metals. The ultimate tensile stress is a measure of the strength of a material. Steel is a strong metal but aluminum is comparatively weak.
2. Ductility is the ability of the material to be drawn out into a smaller cross section by a tensile force. Metals which can be drawn out into a fine wire are said to be ductile.
3. Hardness is the property of a material which allows it to resist wear and penetration.
4. Toughness is the capacity of the material to withstand shock loads without breaking. Brittleness is the opposite of toughness. Some materials can stand repeated blows with a hammer without breaking. These materials are said to be tough. Other materials break easily when struck with a hammer. These metals are said to be brittle. Cast iron is a brittle material but mild steel is tough.
5. Malleability is the ability of a material to be hammered or rolled into a plate without breaking. This is a property very similar to ductility. A malleable material can be beaten or rolled into plates without cracking. Lead is a typical example and it can be beaten out when cold. Other metals, when they are hot can be greatly distorted by hammer blows without cracking.

4. CHEMICAL COMPOSITION OF 300M STEEL

- The Carbon contents various from 0.38 – 0.46%.
- The Chromium Contents ranges from 0.7 – 0.95%.
- The Manganese contents ranges from 0.6 – 0.9%.
- The Molybdenum contents ranges from 0.3 – 0.65%.
- The Nickel contents ranges from 1.65 – 2%.
- The Phosphorous content various from 0.01% (At maximum)
- The Silicon contents ranges from 1.45 – 1.8%.
- The Sulphur content various from 0.01% (At maximum)
- The Vanadium contents ranges from 0.05% (At Maximum)
- Density (lb/cu. in.) 0.283

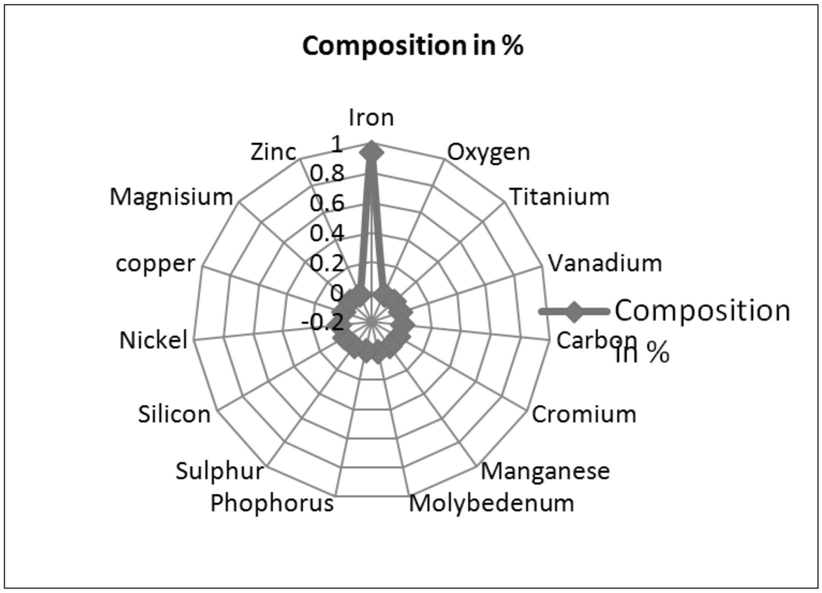

Figure 1: Chemical Composition Of 300M steel Alloy

5. PHYSICAL DATA OF 300 M STEEL

Table 1
Physical Property

Physical Property	*Value*
Specific Gravity	7.83 Kg/m^3
Specific Heat	(Btu/lb/Deg F – [32-212 Deg F]) 0.116
Melting Point	2590 Deg F.
Thermal Conductivity	21 watts/meter.
Density	(lb/cu. in.) 0.283
Mean Coefficient of Thermal Expansion	6.6.

6. SHOT PEENING PROCESS IN 300M STEEL

Shot peening is a cold work process used to finish metal parts to prevent fatigue and stress corrosion failures and prolong product life for the part. In shot peening, small spherical shot bombards the surface of the part to be finished.

The shot acts like a peen hammer, dimpling the surface and causing compression stresses under the dimple. As the media continues to strike the part, it forms multiple overlapping dimples throughout the metal surface being treated. The surface compression stress strengthens the metal, ensuring that the finished part will resist fatigue failures, corrosion fatigue and cracking, and galling and erosion from cavitations.

Shot peening is also used for work hardening to improve wear characteristics, straightening distortions, surface texturing and for creating aerodynamic curvatures for allows for lighter-weight parts that exhibit high wear and fatigue resistance. It is the most economical and effective method of producing and making surface residual compressive stresses to increase the product life of treated metal parts.

Nearly all fatigue and stress corrosion failures originate at the surface of a part, but cracks will not initiate or propagate in a compressively stressed zone. Because the overlapping dimples from shot peening create a uniform layer of compressive stress at metal surfaces, shot peening provides considerable increases in part life.

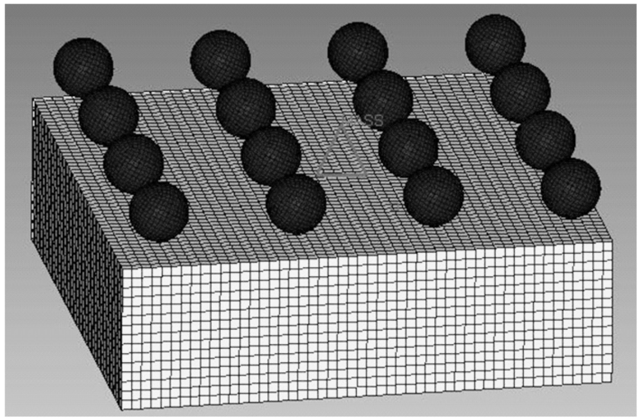

Figure 2: Target mesh model (Hypermesh)

Boundary Conditions:

1. Shot hits target normal to surface under initial velocity 45 m/sec.
2. Shot Distance-1 m
3. Shot Angle-90^o

Target Mesh Model:

Dim = 10 × 10 × 3

Element Type = C3D8 Target Skin membrane element = M3D4R

No of elements = 37500

Nodes are 41616

Shot mesh model as rigid Elements Dim = 1.25 mm dia (16 Nos)

Global element size 0.1 mm

Element type = R_3D_4, R_3D_3

No. of element 8960

No. of nodes are 899

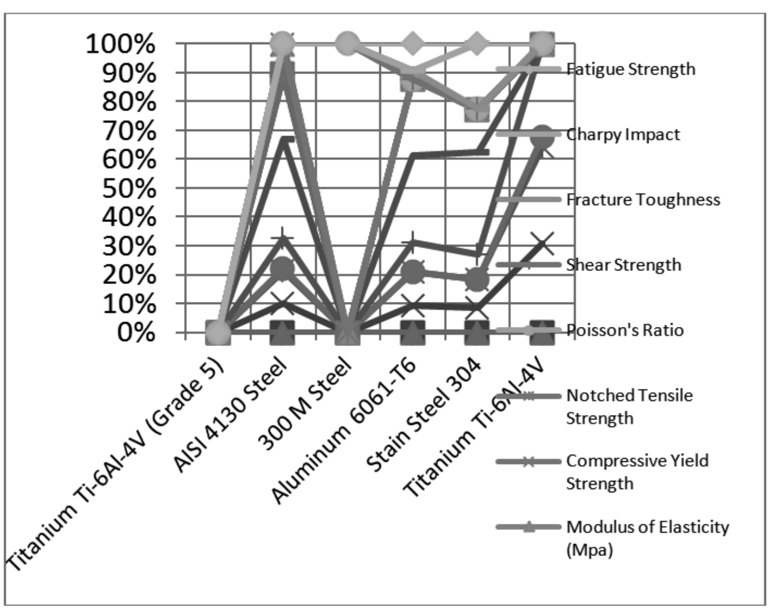

Figure 3: Physical Properties of 300 M Alloy Steel

Compressive stresses are beneficial in increasing resistance to fatigue failures, corrosion fatigue, stress corrosion cracking, hydrogen assisted cracking, fretting, galling and erosion caused by cavitations. The maximum compressive residual stress produced just below the surface of a part by shot peening is at least as great as one-half the yield strength of the material being shot peened.

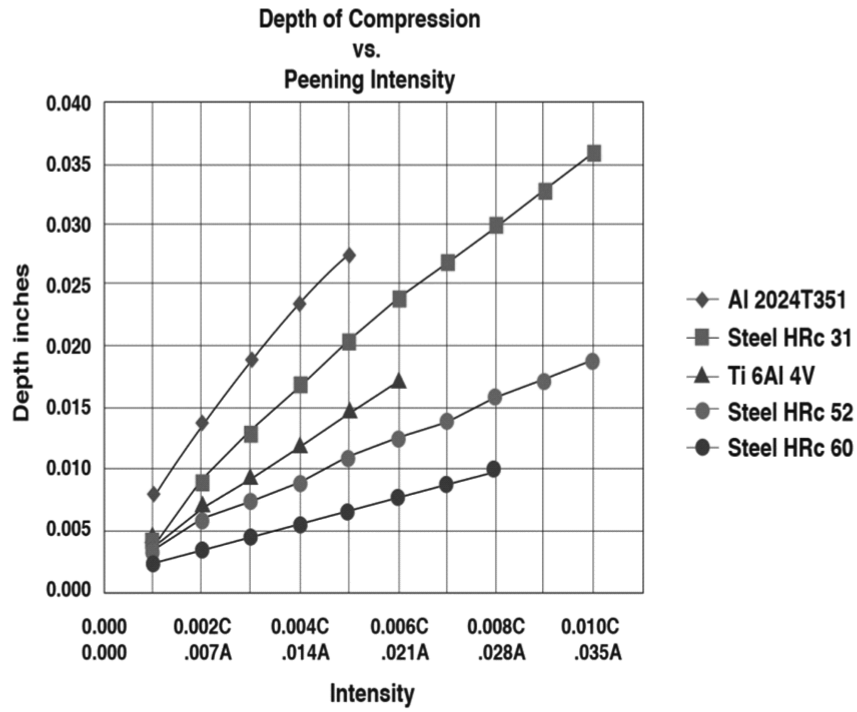

Figure 4: Depth of Compression Vs. Peening Intensity

Shot peening also can induce the aerodynamic curvature in metallic wing skins used in advanced aircraft designs. Additional applications for shot peening include work hardening through cold work to improve wear characteristics, closing of porosity, improving resistance to intergranular corrosion, straightening of distorted parts, surface texturing and testing the bond strength of coatings.

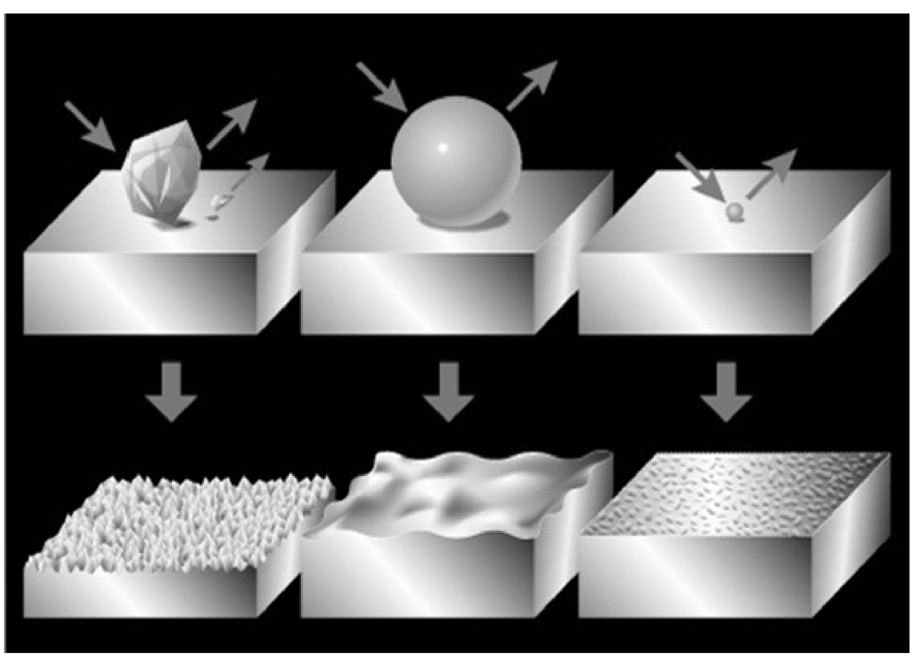

Figure 5: Induced Stress Corrosion

Figure 6: Tensile Stress Corrosion

Shot Peening is cost effective and reliable and can be achieved with Air blasting or Wheel blasting depending on capacities, part size and requirements. Landing gears or turbine blades of aircraft, artificial joints in the medical industry, gear wheels, gear shafts, valve springs, suspension springs, connecting rods, and many other parts in various industries are shot peened every day.

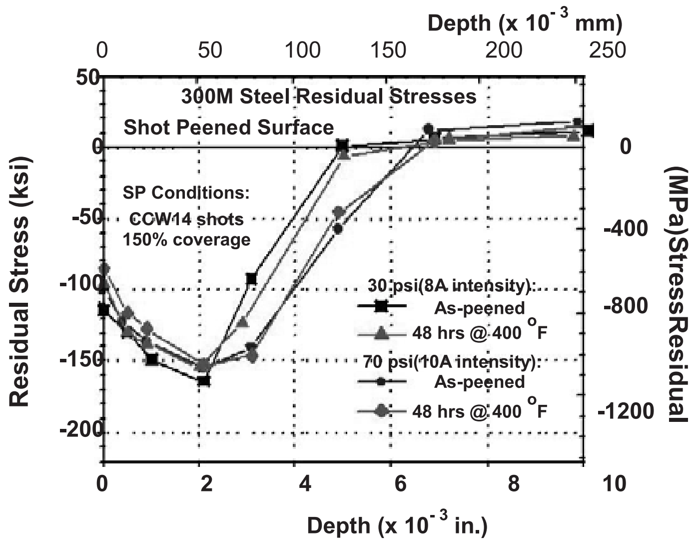

Figure 7: SP subsurface residual stress distributions

The HCF and corrosion fatigue performance of 300M steel is shown in Figures 6 as maximum stress S-N curves. The baseline material performance with and without the EDM notch and salt exposure. The unnotched baseline fatigue strength (endurance limit at 107 cycles) is nominally 1035 MPa (150 ksi). In the presence of a neutral salt solution, the baseline corrosion fatigue strength drops dramatically to about 205 MPa (30 ksi).SCC test results show the untreated baseline material had SCC time to failure at 1034 MPa (150 ksi), at 1138 MPa (165 ksi) and 12.9 hrs at 1241 MPa (180 ksi), respectively. The corrosion fatigue , shot peened and baseline 300M steel a compressive layer an order of magnitude deeper and more compressive than 8-10A in shot peening.

7. CONCLUSION

Malfunction of landing gear have been one of the serious cause of numerous accidents and incidents though out the aviation history. So as to increase the corrosion fatigue of 300M steel as it is one of the widely used steels in landing gear a systematic experimental process is undertaken.

Generally there are four techniques to increase the corrosion fatigue of a metal From this paper we have accounted the surface enhancement of 300 M steel by using shot peening process and positive results are accounted.

APPLICATION OF RESULTED DATA: This data will account as a potential asset in a reference on Industrial processing and manufacturing of 300M steels in aircraft industries. Also, the data will be beneficial in ameliorating further researches in material sciences of 300M steel so as to reduce its failure properties. For Example, manufacturing of finished products could positively undergo the shot peening process to improve its corrosion fatigue life with a final process of manufacturing.

Few Industries have already adopted the technique for similar alloy metals for other different purposes. The application of shot peening process in 300 M steel will for sure serve as a positive investment supporting safety measures.

In Conclusion, the shot peening process applied in 300M Steel does not only reduce the corrosion fatigue, But also enhances the overall property of the material to a defined extent and is a boon to the world of material sciences.

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