LAMBDA Technologies Group

Diffraction Notes

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THERMAL STABILITY OF RESIDUAL STRESS IN TITANIUM NITRIDE COATED TITANIUM

INTRODUCTION

Titanium nitride (TiN) is a hard ceramic material frequently used as a coating on titanium, steel, and aluminum alloys – it is easily identified by its characteristic gold appearance. The thin coating, often less than 5 micrometers in thickness, can provide a hard, smooth, corrosion and wear resistant surface prolonging the life and performance of many different parts and components such as drill bits and machining tools, medical devices and implants, and aerospace components.

The primary method of application for a TiN coating is by means of a physical vapor deposition (PVD) process, which typically requires a vacuum and peak temperatures of up to 400 °C for 3 hours. Temperatures of this magnitude and duration can be problematic for components designed with beneficial compressive residual stresses. Residual stresses can be significantly relaxed from thermal exposure especially for processes like shot peening that introduce high levels of cold working. The effect of cold work on the thermal stability of residual stress in various engineering alloys has been extensively studied over the years by the engineers at Lambda (simply search for "thermal" on the Technical Publications page of our website).

Low plasticity burnishing (LPB®) is capable of inducing high residual compression with minimal cold work, which gives it the unique capability to withstand thermal relaxation during the TiN coating process. Likewise, reducing the cold work produced by a shot peening process by peening to less than 100% coverage can also improve thermal stability, particularly when the process has been optimized and proven to adequately enhance fatigue life with the prescribed coverage.

The engineers at Lambda designed a study to investigate the thermal stability of the residual compression produced by LPB and various shot peening processes when subjected to various TiN application processes. This article contains a subset of the results generated.

MATERIAL PROCESSING AND TESTING

Titanium alloy Ti-6Al-4V Grade 5 mill annealed test coupons were sectioned from 0.5 inch thick plate. Chemistry and tensile properties were verified by third party testing. All samples were then chemically etched to remove 0.003-0.004 in. of material in order to ensure a uniform low-stress and low-cold work starting surface. The samples were then divided into groups for processing with the various surface enhancement treatments. These groups included: etched, glass bead peened (GBP) to 200% coverage, 64% coverage peened with CCW14 shot at 8A intensity, 87% coverage peened with CCW14 shot at 8A intensity, and LPB+GBP. GBP was added to the LPB process as a recommendation by the TiN coating supplier to ensure proper adhesion to an otherwise extremely smooth LPB surface. Coupons of each group were then sent out for an application of a TiN coating. The entire process reportedly took a total of 7 hours in vacuum with a mean temperature of 376 °C and a maximum temperature of 400 °C. The coating thickness was reported to be 0.0001 in., which was later verified with SEM cross-sectional evaluation.

Residual stress and cold work were measured as a function of depth for each sample condition using the x-ray diffraction $\sin^2(\psi)$ method.

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RESULTS AND SUMMARY

The residual stress and cold work distributions are shown in the figures. While the TiN PVD process resulted in stress relaxation for all surface treatment processes, the relative amount of relaxation was proportional to the level of cold working.

- High cold work shot peen processed coupons experienced ~54% reduction in maximum compression, compared to ~38% reduction for the lower cold work shot peen coupons
- LPB processed coupons experienced less than 35% reduction in maximum compression as a result of TiN processing
- LPB and the low coverage shot peening process retained the highest amount of residual compression, with LPB showing at least 30 ksi greater maximum compression and over 0.020 inches deeper total depth of compression
- LPB processing produced a depth of compression over 3.5 times greater than any of the shot peen processes
- TiN coating process did not cause a significant reduction in total depth of compression

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