Investigation of nitriding surface treatments to improve water droplet erosion resistance of Ti6Al4V

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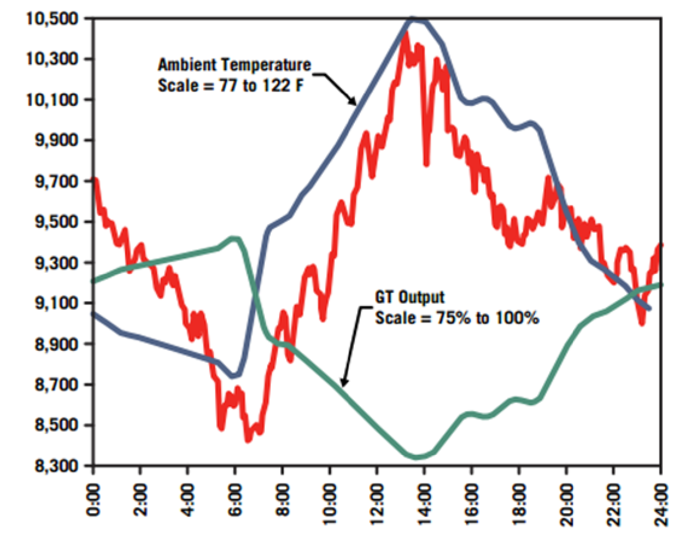
Motivation and Objective

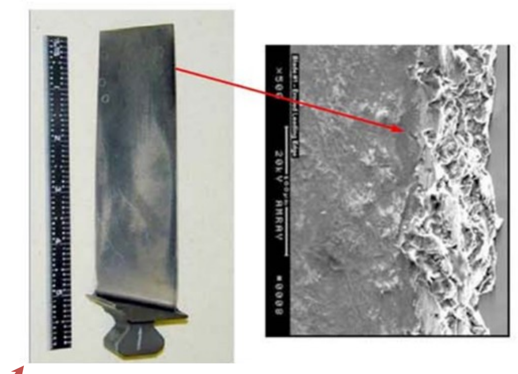
Improving the turbine efficiency is an important issue for the power generation industries. Spraying water droplets on the incoming air to the turbines compressor has been used as the most applicable method to decrease air temperature leading to increase mass flow rate and as a result more turbine output power.

Temperature, 1°F ↑ ⟶ Turbine efficiency, 0.3-0.5% ↓

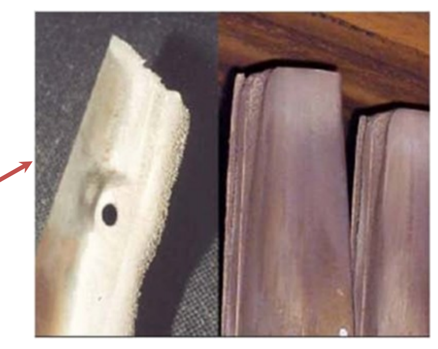
So, the fog cooling is necessary and increases the turbine efficiency. But, there is a problem caused by water droplets hitting the blade. Impinging the water droplets and rotating blades during the cooling process leads to their erosion called liquid droplet erosion (LDE) especially on the leading edges of compressor blades. Therefore, final efficiency of turbines will be reduced due to mechanical degradation of compressor blades and it is not desirable.



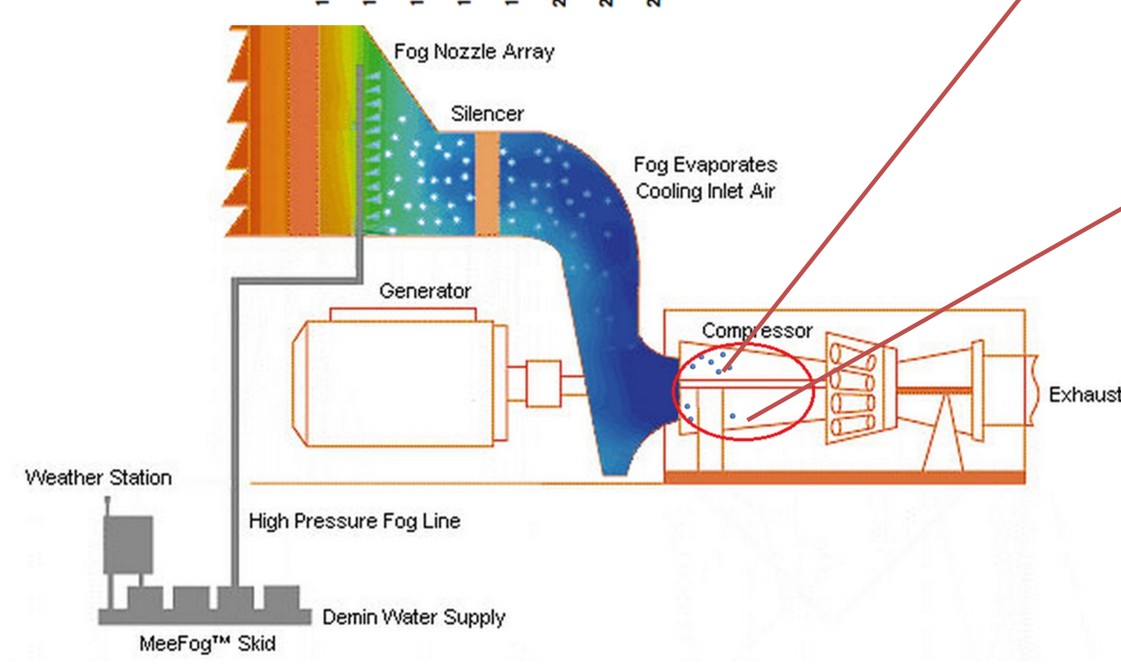
The hourly profiles for power generation by a combustion turbine (CT), ambient temperature versus GT output



LDE damage to 7FA engine compressor blade



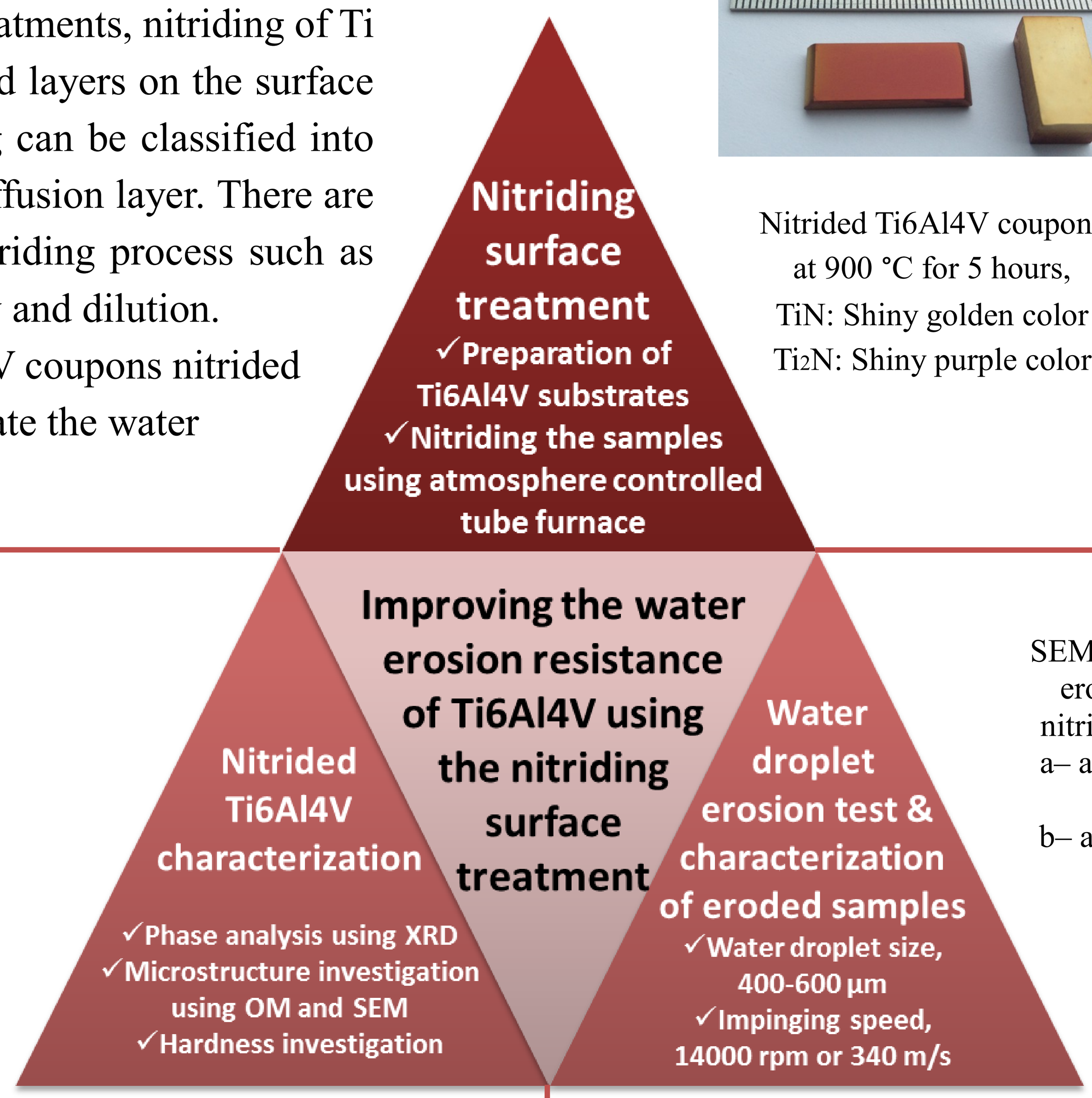
LDE damage to LP steam turbine blades

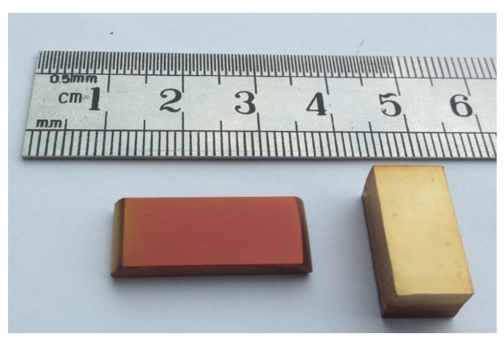


Schematic of fog cooling in the gas turbines with identified entering droplets to the compressor

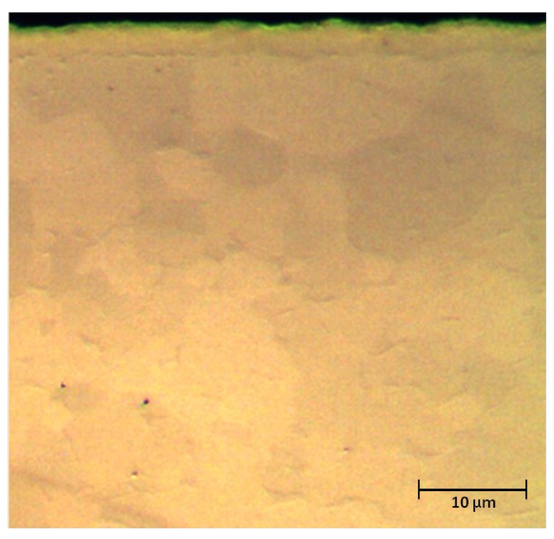
Methodology and Results

Several surface treatments such as thermo-chemical treatments have been studied to improve the erosion properties with increasing the surface hardness approach. Among the thermo-chemical treatments, nitriding of Ti alloys seems promising due to the formation of hard layers on the surface of titanium. The layers formed during the nitriding can be classified into two main groups, thin compound layer and thick diffusion layer. There are several effective process parameters during the nitriding process such as nitriding time and temperature, nitrogen purity, flow and dilution.
These parameters is being modified and the Ti6Al4V coupons nitrided at the optimized parameters will be used to investigate the water droplet erosion.





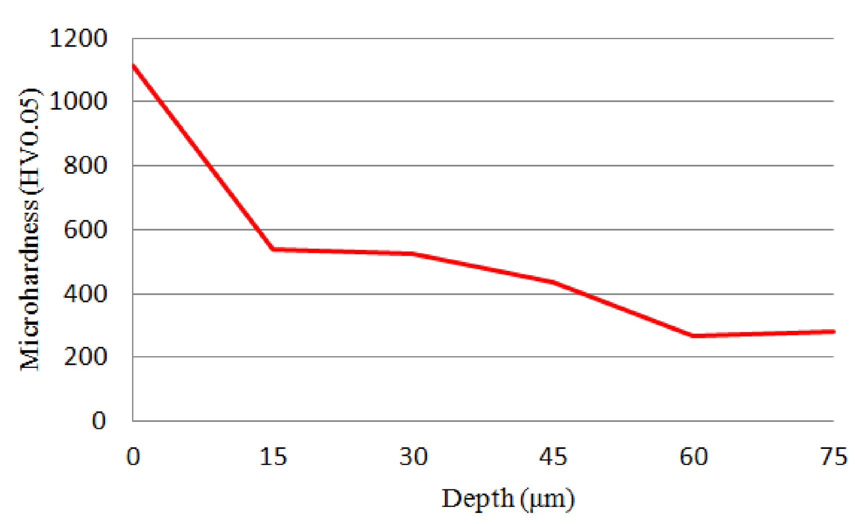
Nitrided Ti6Al4V coupons at 900 °C for 5 hours, TiN: Shiny golden color Ti_2N: Shiny purple color



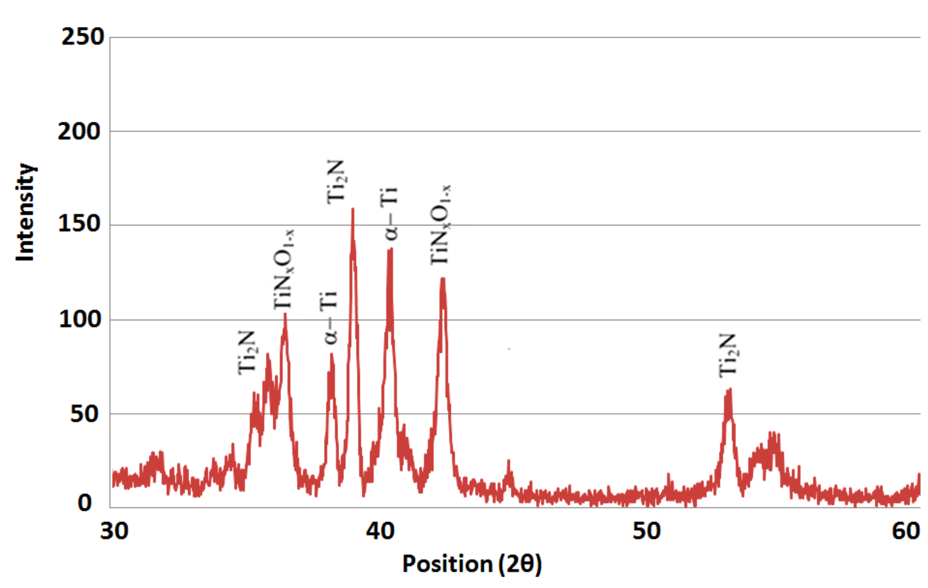
Compound layer including TiN_x, Ti_2N phases

Diffusion layer including α - Ti (N) phase

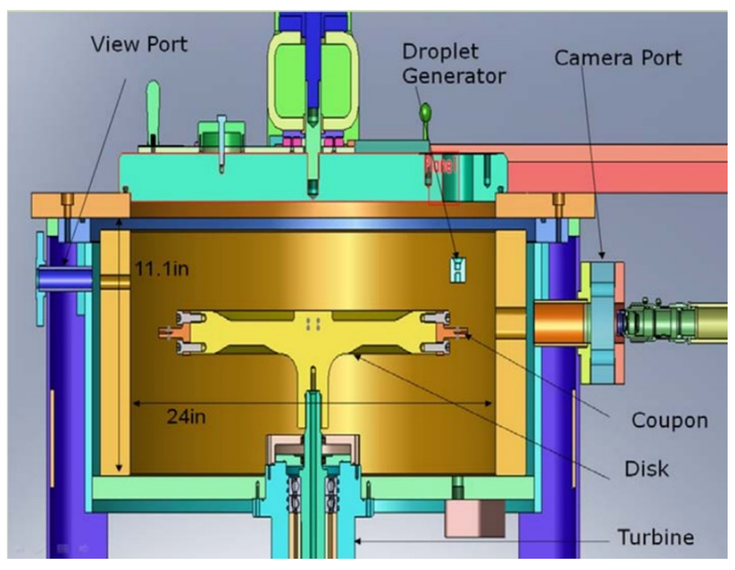
Cross-sectional micrograph of nitride Ti6Al4V taken by optical Microscope, The dual phase structure of Ti6Al4V (α-β) can be seen in this micrograph.



Microhardness profiles of Ti6Al4V alloy after gas nitriding at 900 °C for 5 hours, 1115 HV as surface hardness for compound layer with 3 µm and around 510 HV for the diffusion layer

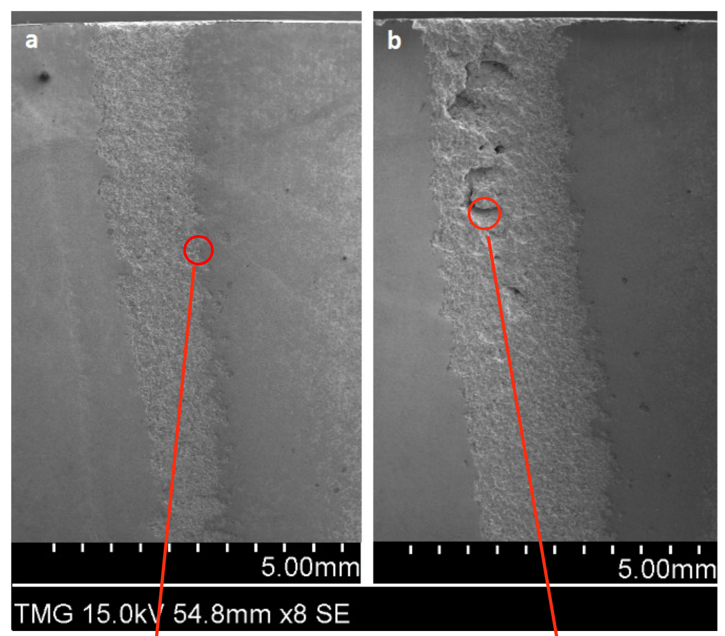


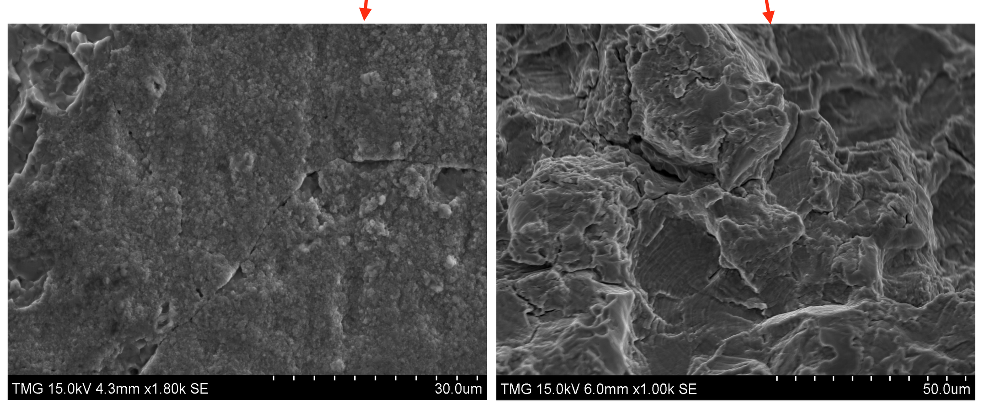
X-ray diffraction patterns of Ti6Al4V nitrided at 900 °C for 5 hours



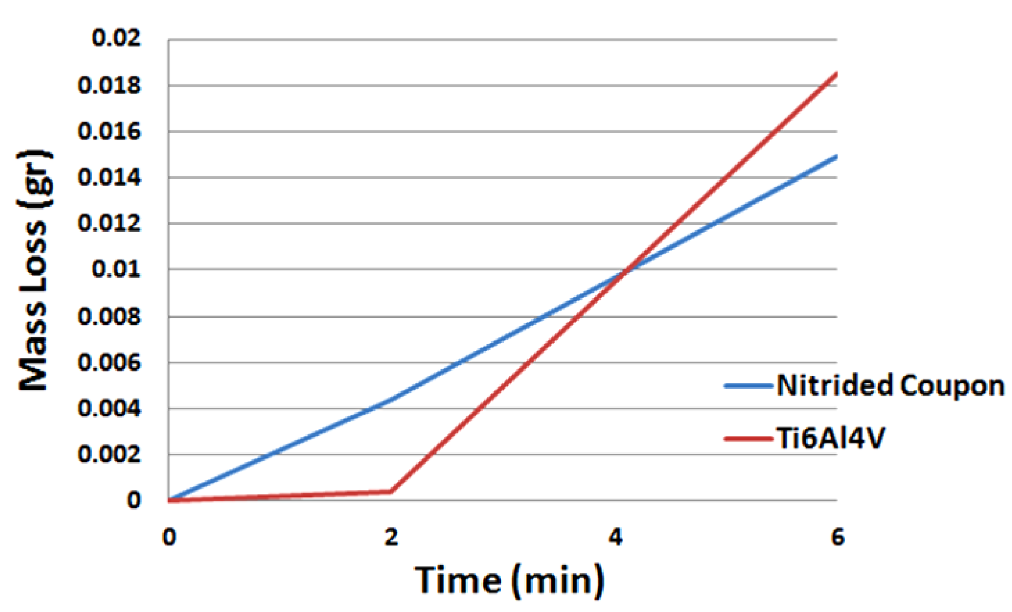
Water erosion rig recently installed in Concordia University
-Very good control on the process parameters like impinging speed or droplet size
-Reaching very high impinging speed (500 m/s)

SEM micrographs of eroded Ti6Al4V nitrided for 5 hours
a– after 2 min LDE erosion
b– after 6 min LDE erosion





The frequent droplet impingements to the surface of sample results in cyclic loading and after passing the incubation period of erosion damage, the propagated cracks would be merged and lead to material lost. Because of top layer brittleness, many cracks on the surface of coupons beside the erosion groove can be seen.



The initial erosion test has been done on the nitrided Ti6Al4V for 5 hours.
First run was 2 min and second one was 4 min LDE erosion.
It seems the compound layer has been removed at the beginning of the test leading to more weight loss for the nitrided coupon. But at the second run less mass loss for the nitrided specimen due to the diffusion layer can been seen.

Conclusions and future works

- The initial erosion test results showed that the very hard and brittle layers can not be assumed as the best surface treatment to improve LDE erosion especially when their adhesion strengths to the substrate are not appropriate (for example TiN or Ti_2N formed by gas nitriding method). But, the thick diffusion layer below the nitrided phases showed promising behaviour.
- The nitridng parameters will be modified to have proper conditions for diffusion layer. The nitrided coupons will be used to investigate the the water droplet erosion damage at various conditions.

References

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- C. Gerdes, A. Karimi, H.W. Bieler, ‘Water droplet erosion and microstructure of laser-nitrided Ti-6A14V’, Wear 18fG187 (1995) 368-374

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