Cold Spin Test (CST) of Silicon Nitride Discs for Jet-Engine Applications

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- Silicon nitride - process flow chart.
- Cold spin test - Preparation.
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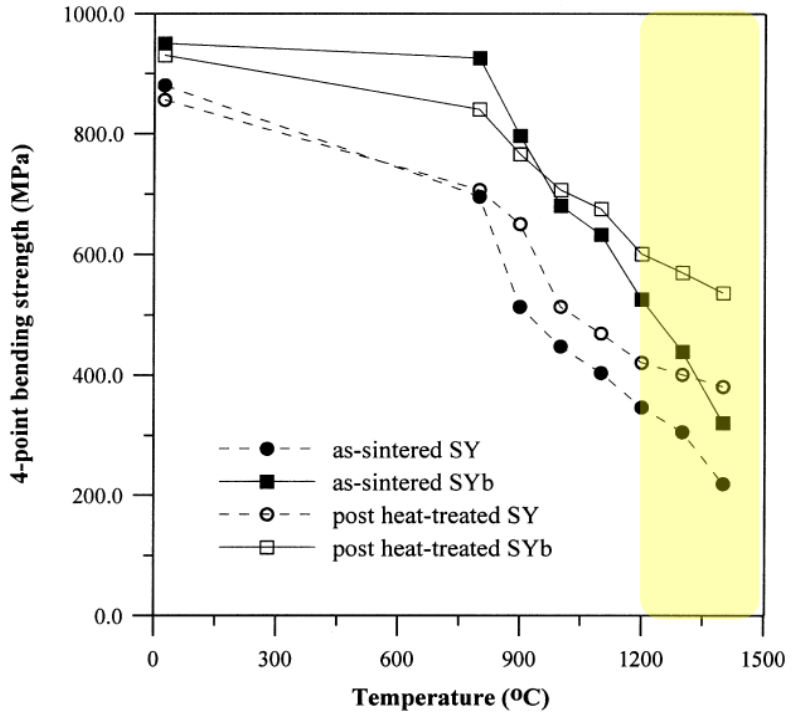
- Summary and future challenges.

Motivation and Research Objectives

Silicon Nitride

Combines excellent high-temperature mechanical properties, resistance to oxidation and thermal shock, making it a promising candidate for high temperature jet engine parts.



More efficient engines:

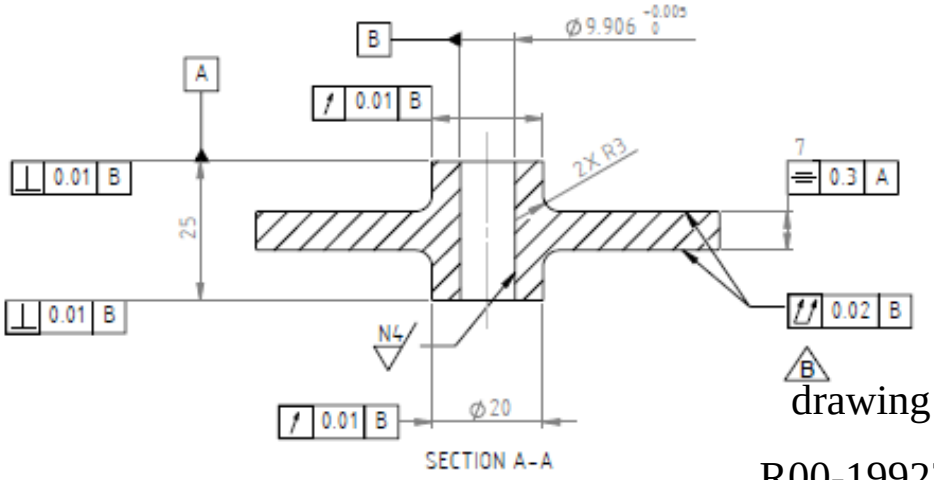
- Low density 3.25 gr/cm^3
- Higher turbine inlet temperature.
- Reduction in cooling needs.

Effect of Y2O3 and Yb2O3 on the microstructure and mechanical properties of silicon nitride, Horng-Hwa Lu, Ceramic international, V. 27, p. 621, 2001

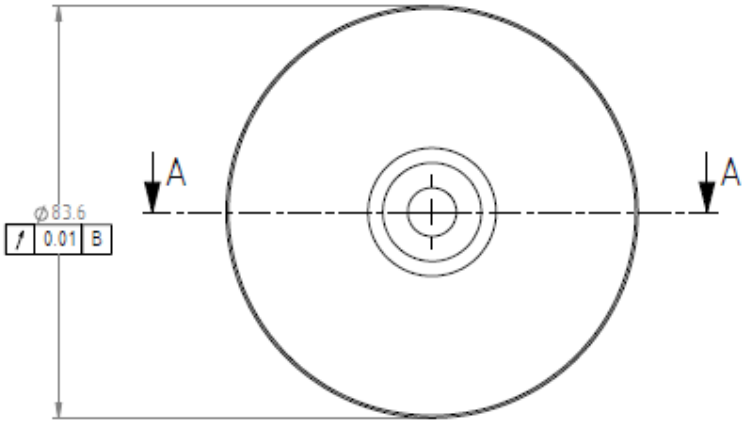
Cold Spin Test (CST)

Research objectives:

1. Assessing the feasibility of using RAFAEL's developed Silicon Nitride for jet-turbine engine applications.
2. Evaluation of the mechanical durability by CST at jet-engine's RPM (115,000 RPM).



drawing R00-199236



Silicon Nitride - Process Flow Chart

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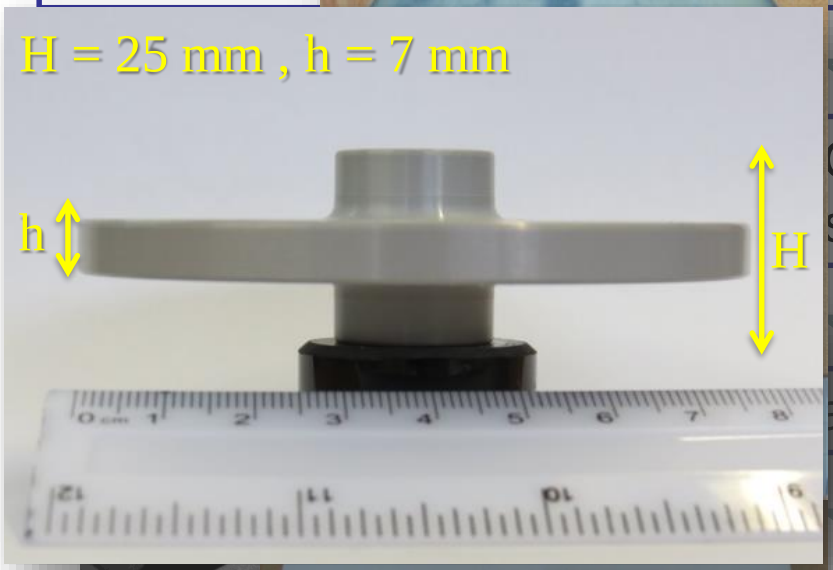
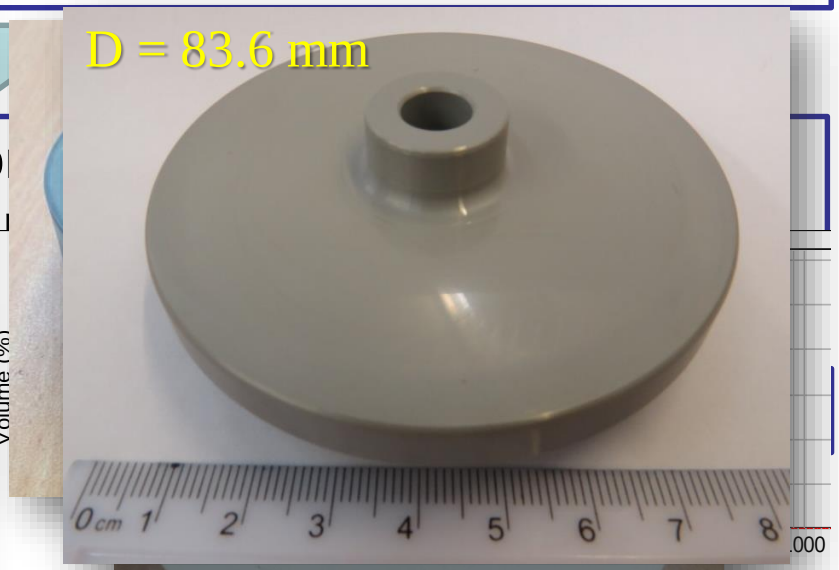
Granulation:

Mixing silic ds and binder aids (organic system)





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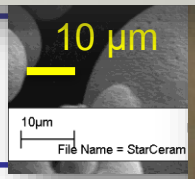
Volume (%)



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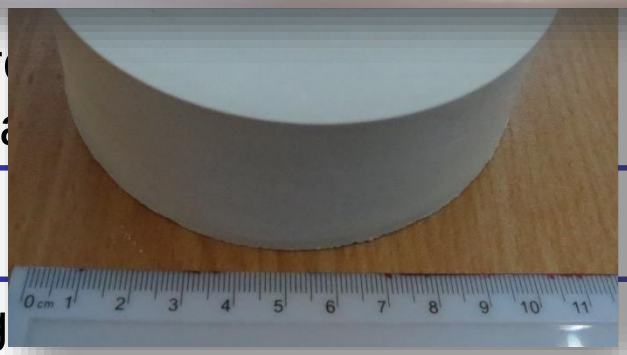

Machining

Cold Spin Test (CST) - Preparation

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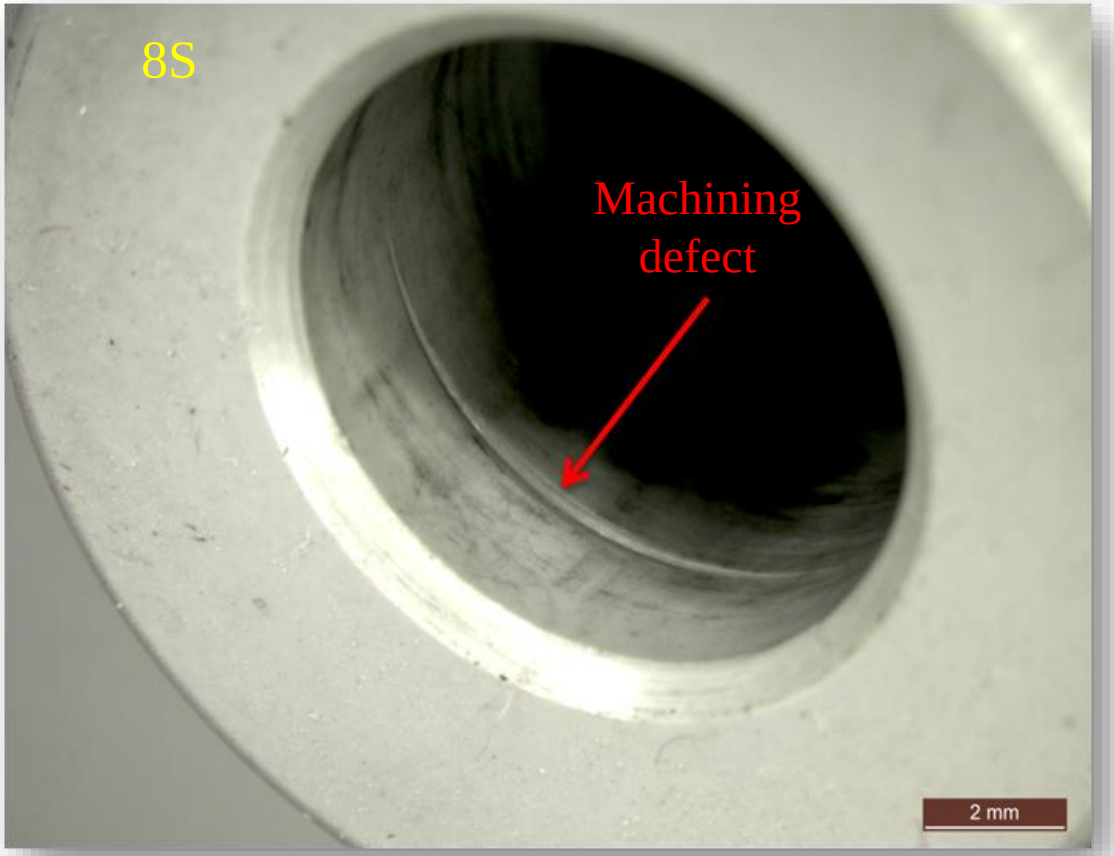
Two silicon nitride discs were manufactured (8S and 5S).

Characteristics	Requirements	8S	5S
Density [%TD] TD=3.25 gr/cc	>97.5% TD	97.6	97.6
Bending strength [MPa] 8 specimens	>600 MPa	642.1 σ=28.1	642.6 σ=19.0
Dimensional inspection	drawing R00-199236	Minor non-conformances	Minor non-conformances

CST - Preparation - Stereoscope inspection

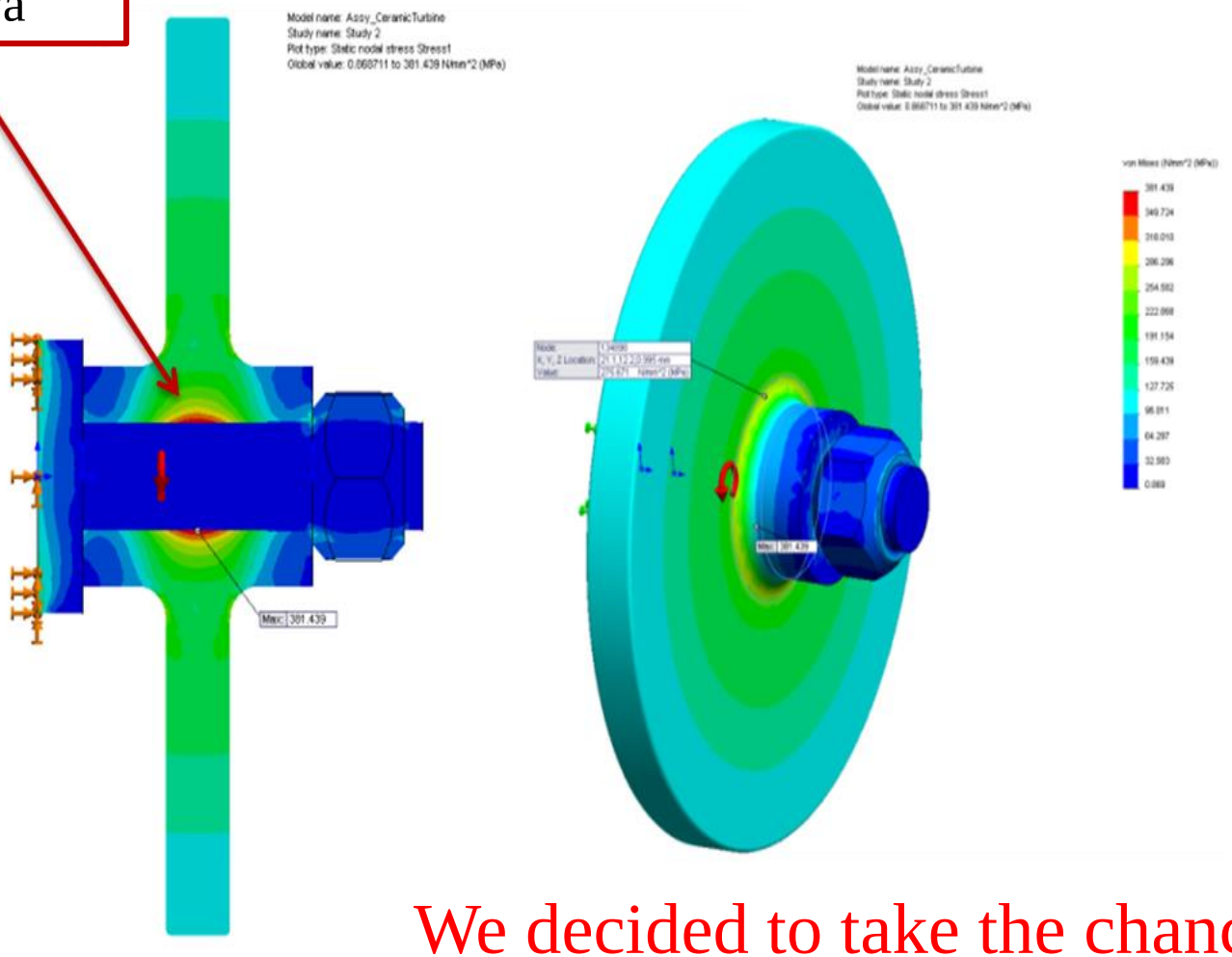


Ceramics are highly sensitive to surface defects.

Should this part be incorporated in the CST?

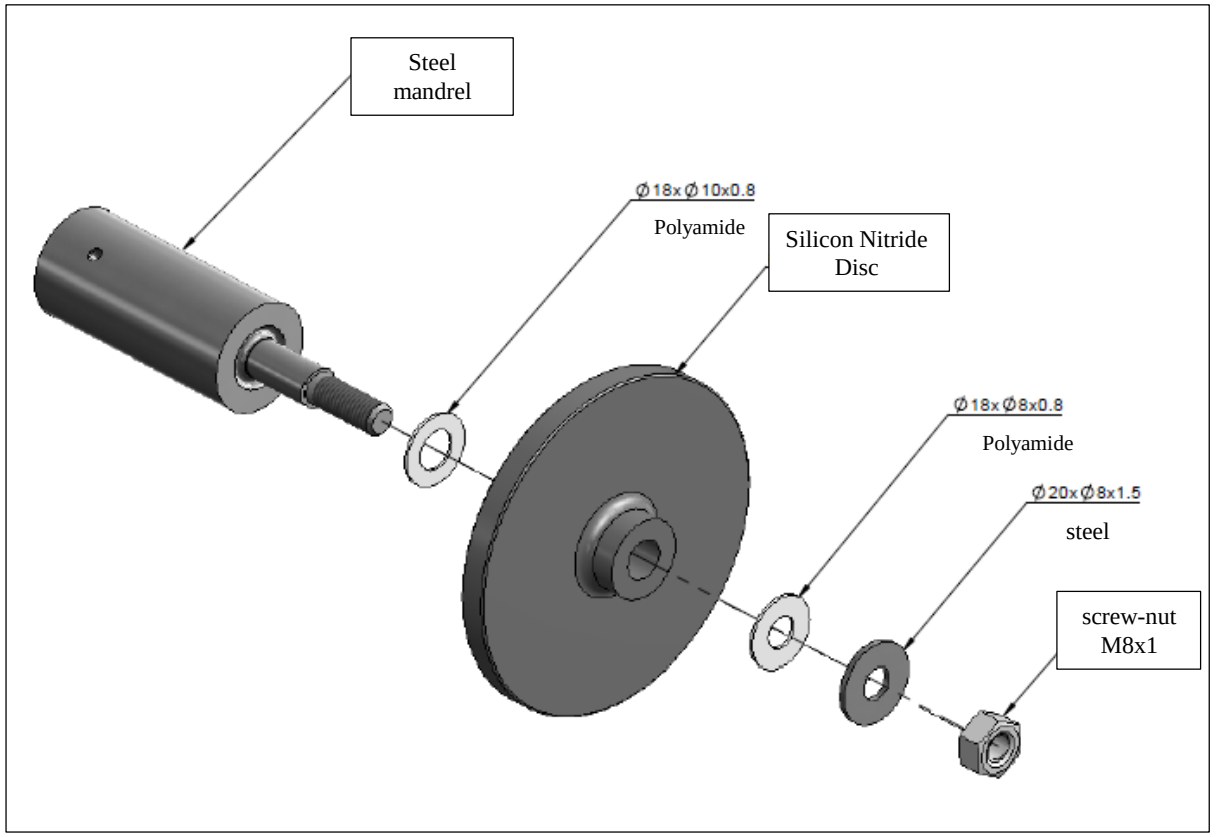
CST - Preparation – Stress Analysis

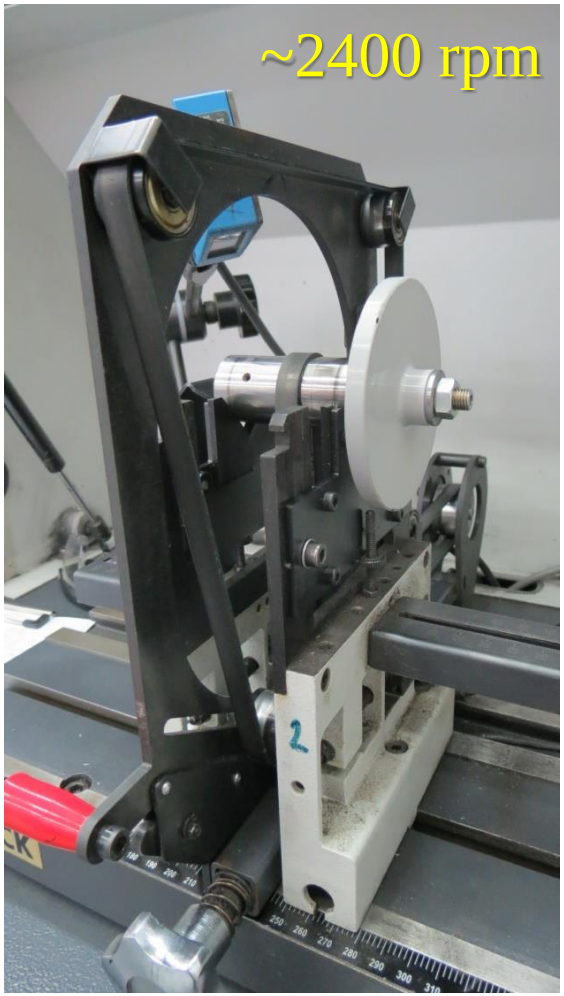
Maximum Stress
395 MPa



We decided to take the chance.

CST - Preparation - Balancing



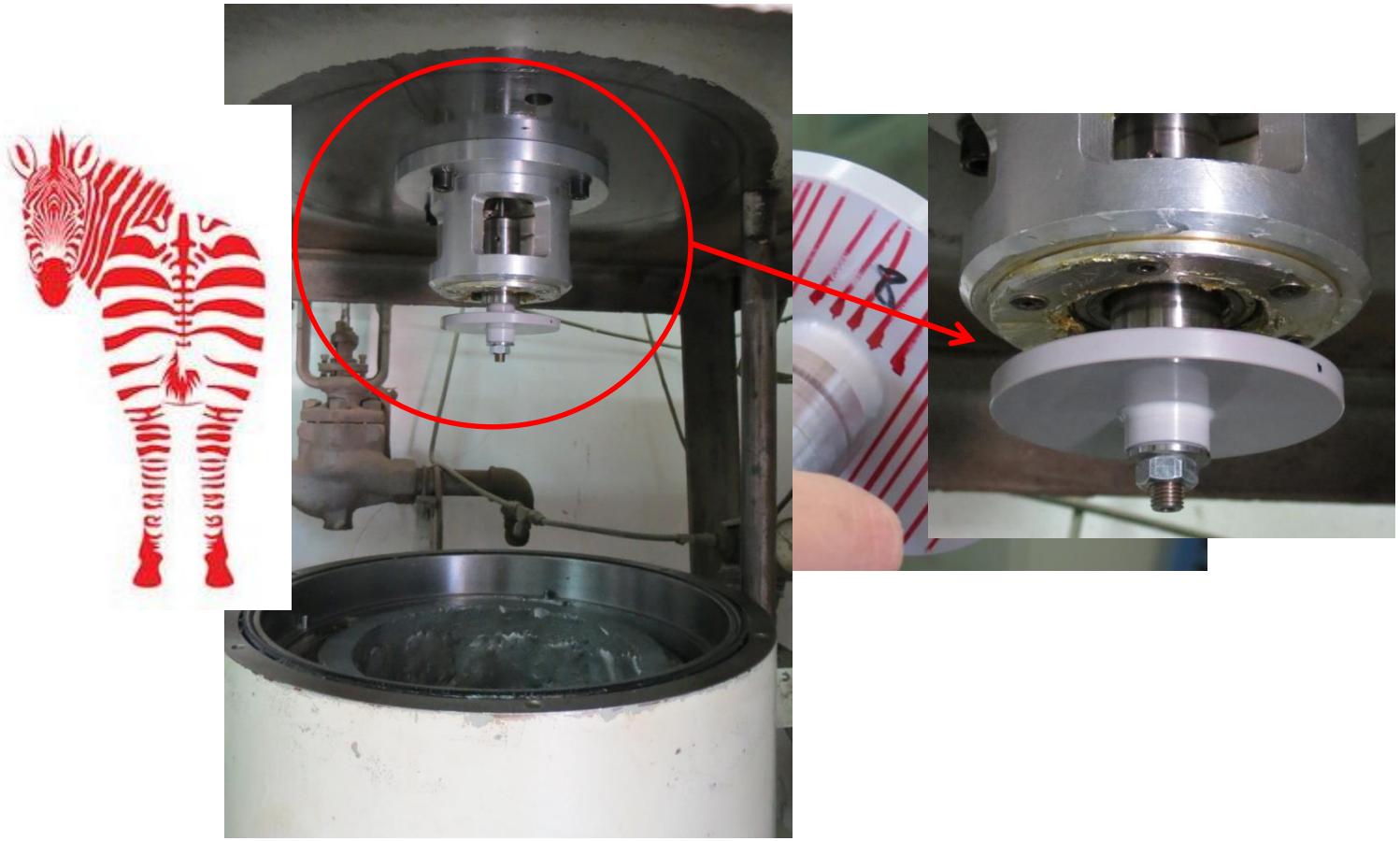


- Material was removed by diamond grinding tool.
- High Dynamic balancing (0.1 gr·mm) was hardly achieved.
- Finally, the parts were only statically balanced (0.1 gr·mm).

The Cold Spin Test (CST)

Cold Spin Test (CST)

- The CST was done at T.A.T Technologies's test rig.
- Static balancing was checked on-site prior to testing.



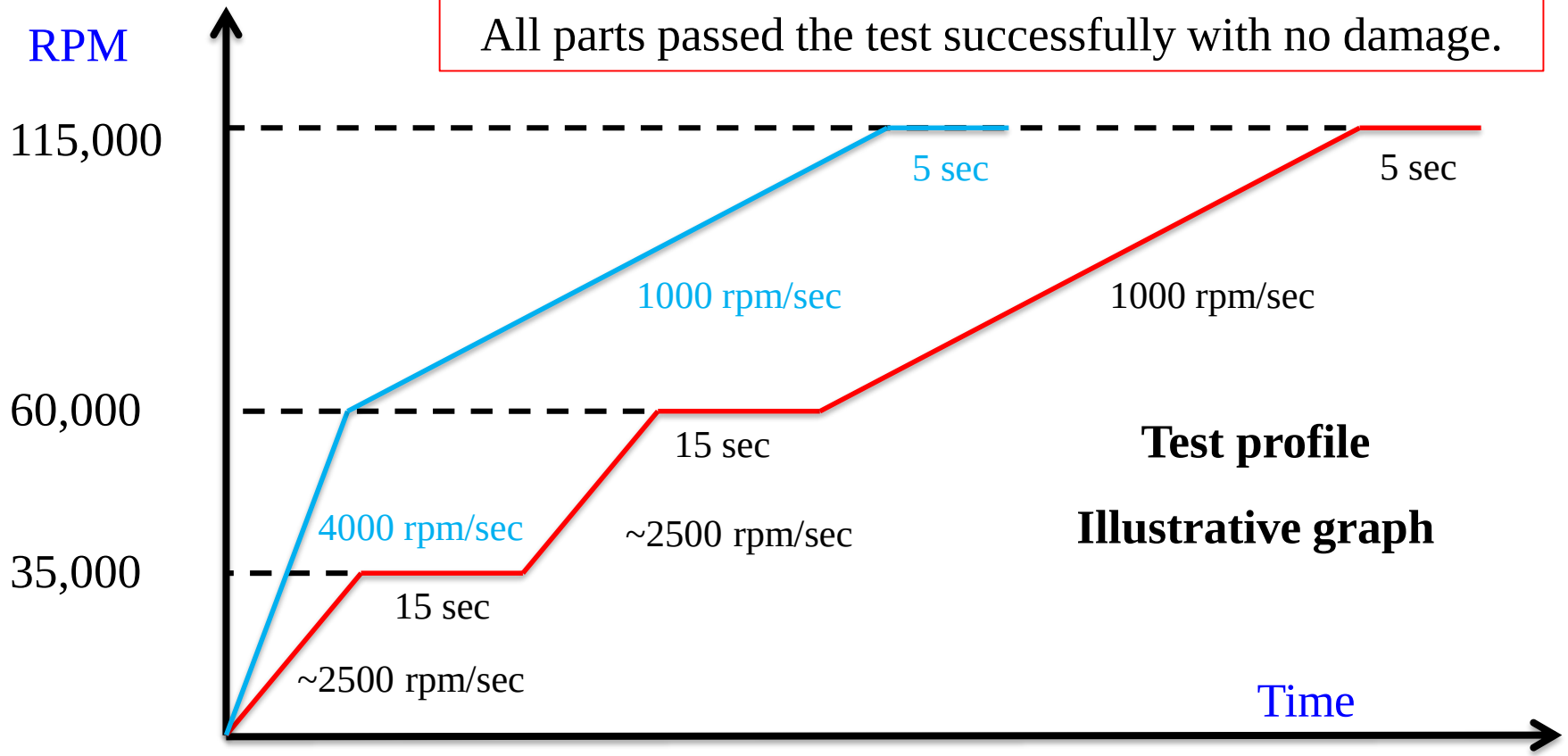
Cold Spin Test (CST)

1st Test: 5S

2nd Test: 8S - Contains the surface defect.

3rd Test: 8S - Contains the surface defect (faster profile: 0 to 115,000 rpm in ~50 sec).

All parts passed the test successfully with no damage.



Test profile

Illustrative graph

Summary

•Silicon nitride fabrication process was developed to achieve required material properties.

•Large parts showed a very narrow strength distribution.

•Silicon nitride discs were manufactured, complying with the CST required specifications.

•All the silicon nitride discs successfully passed the CST.

Future Challenges

•Optimization of the fabrication process.

•Manufacturing a real silicon nitride turbine (blades included).

•High temperature material characterization and hot spin test.