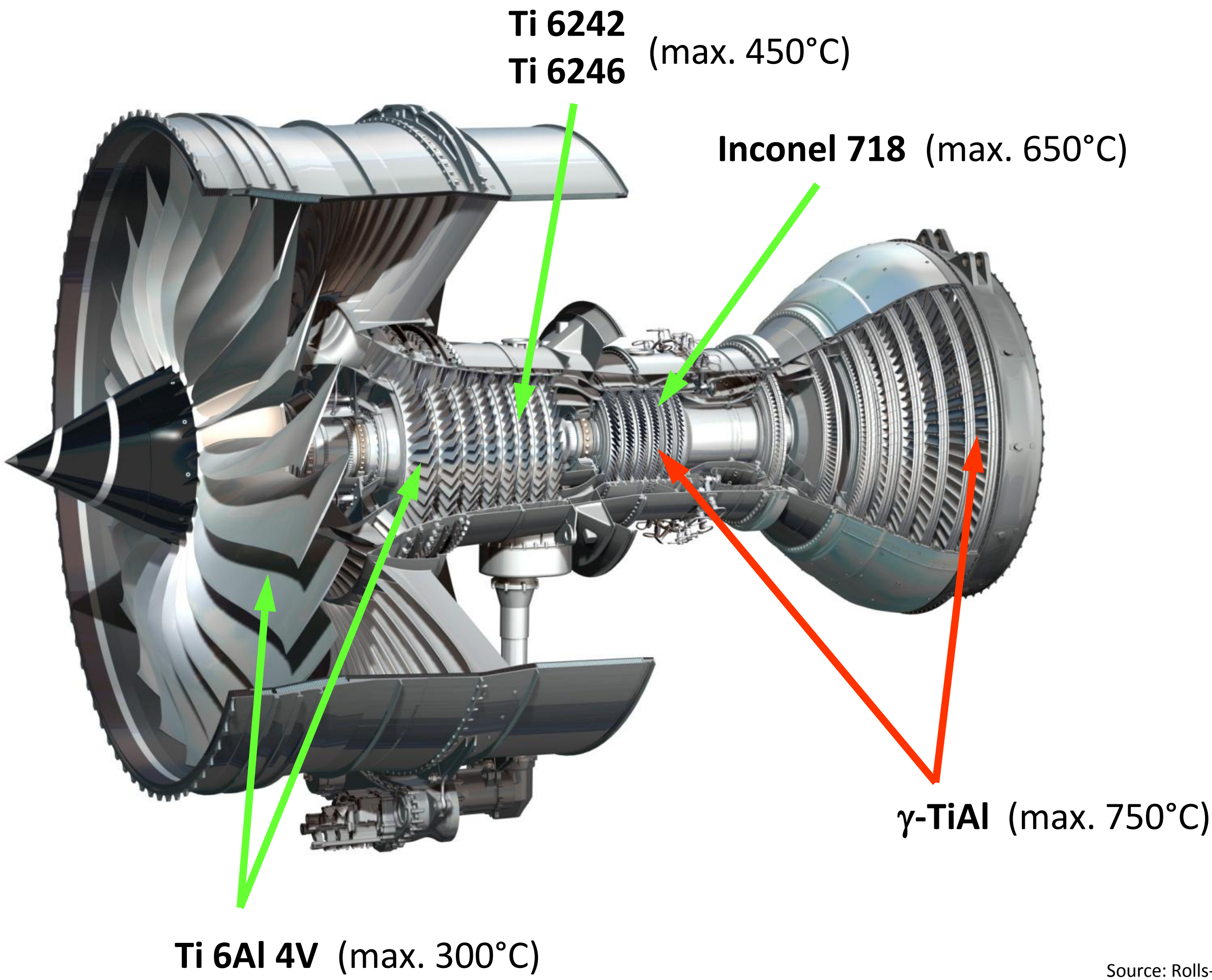
Surface effects on mechanical properties of materials for elevated temperature applications

R. Steinert, J. Lindemann, O. Berdova, M. Glavatskikh, C. Leyens

Chair of Physical Metallurgy and Materials Technology
Konrad-Wachsmann-Allee 17
03046 Cottbus, Germany

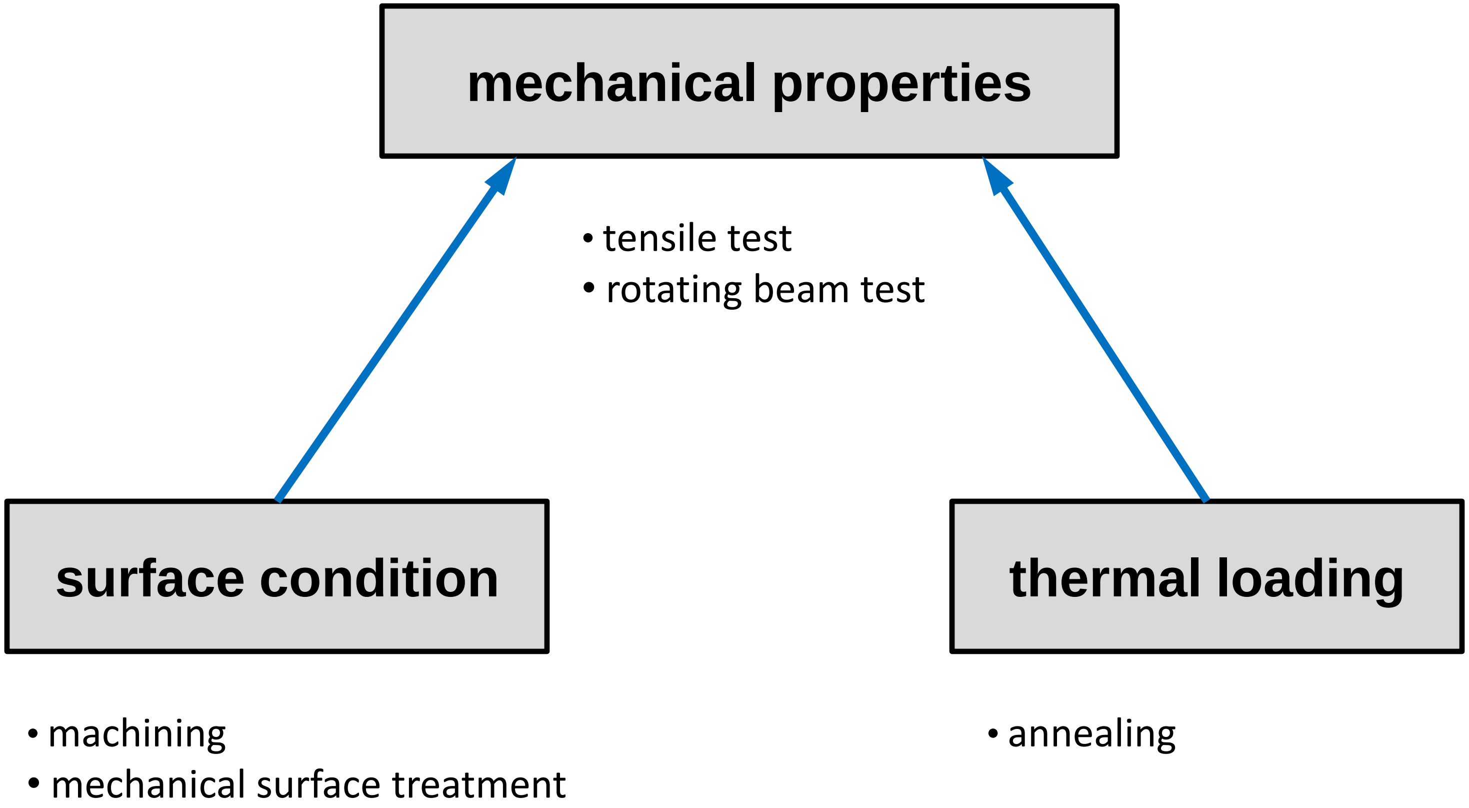
Contact: steinert@tu-cottbus.de

Materials for aero engines

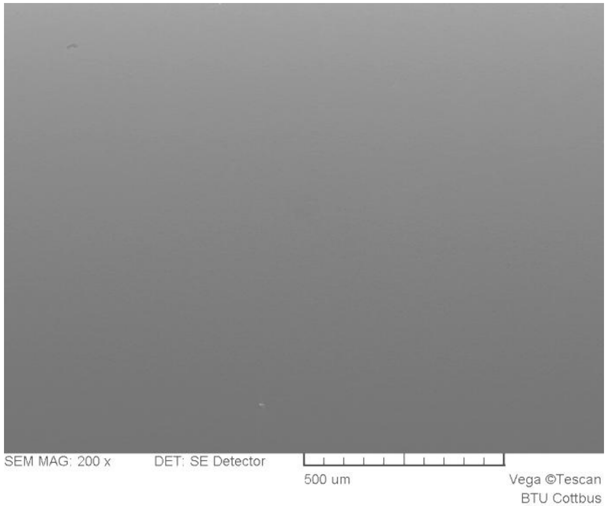


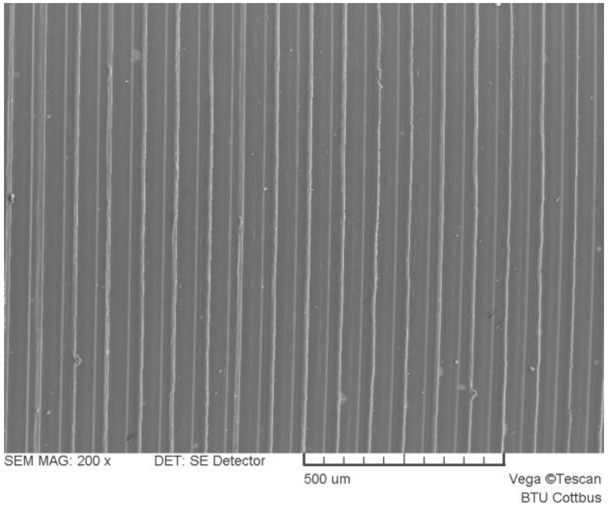
Source: Rolls-Royce

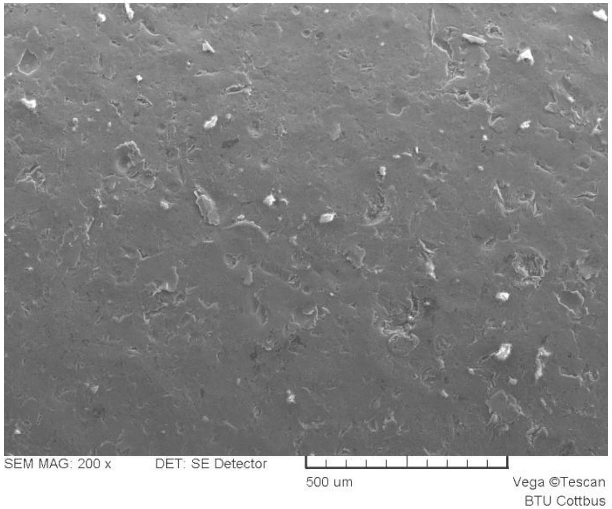
Factors affecting mechanical properties



Surface conditions







electrolytically polished

R_a = 0,1µm
R_y = 0,8µm

roller burnished

R_a = 0,4µm
R_y = 3,0µm

machined (turned)

R_a = 1,1µm
R_y = 7,6µm

shot peened

R_a = 1,4µm
R_y = 10,6µm

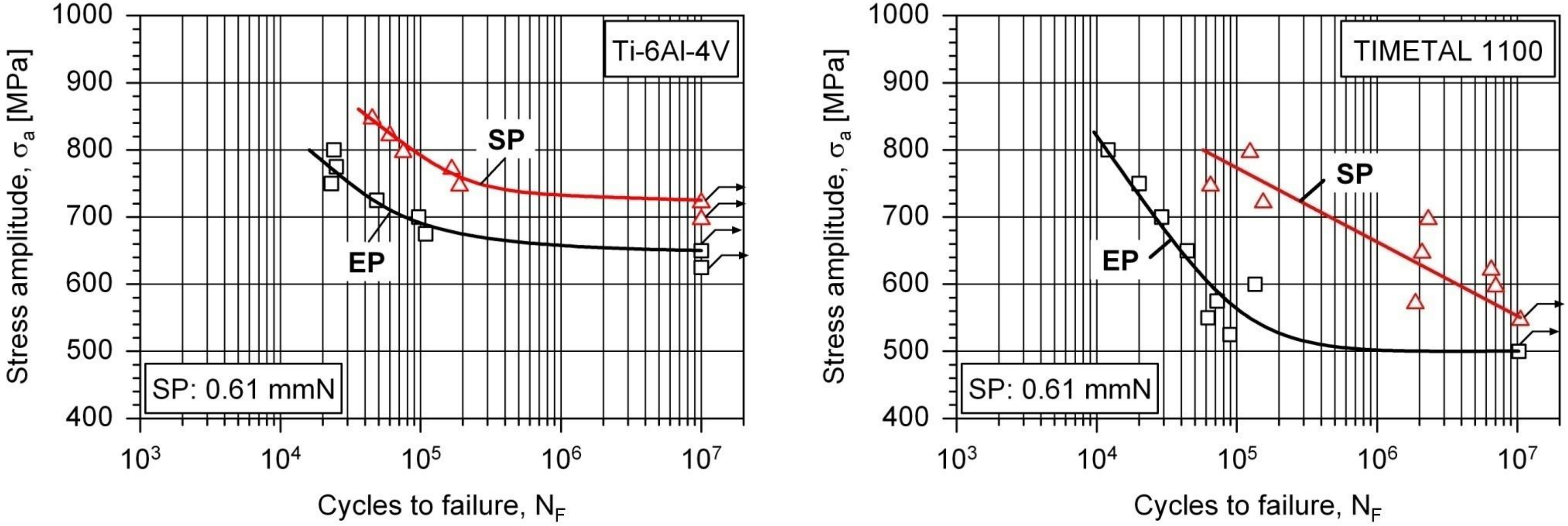
Tensile properties at room temperature

Material	Surface condition	Mechanical properties			
		E [GPa]	$R_{p0,2}$ [MPa]	R_m [MPa]	A_5 [%]
Titanium alloy (Ti 6Al 4V)	Electr. polished	105	998	1096	11,5
	Turned	104	1000	1106	11,9
	Shot peened	105	936	1089	12,6
γ-TiAl (TNB, B C)	Electr. polished	159	904	946	1,3
	Turned	162	917	1074	1,7
	Shot peened	162	904	1063	1,5
	Roller burnished	164	887	1004	1,3

No influence of the surface condition on the tensile properties

Fatigue strength after mechanical surface treatment

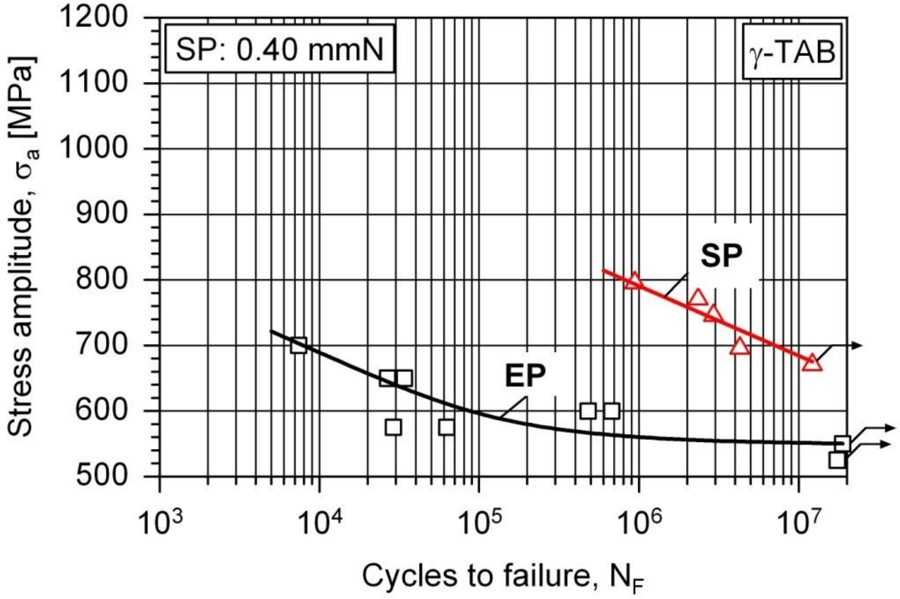
Titanium alloys

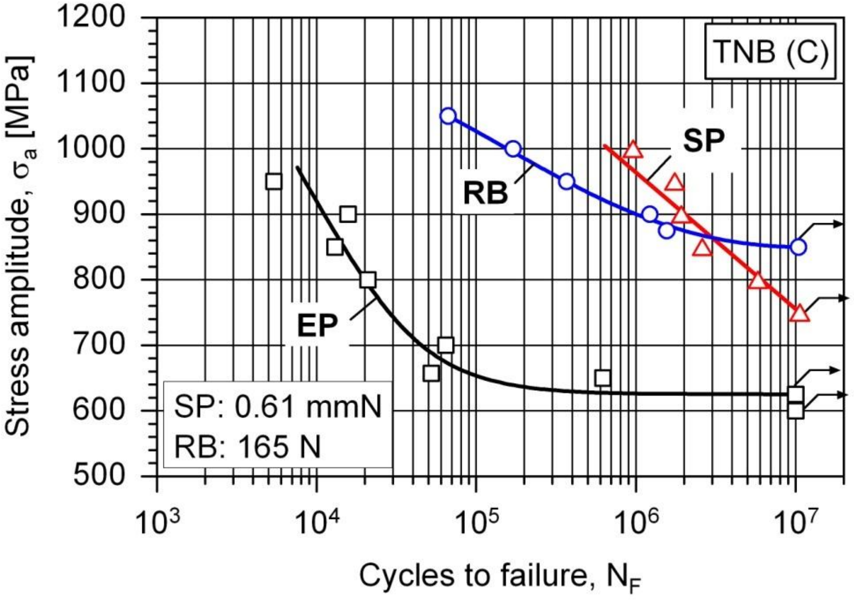


~ 11% improvement of fatigue strength through shot peening

Fatigue strength after mechanical surface treatment

γ-Titanium aluminides



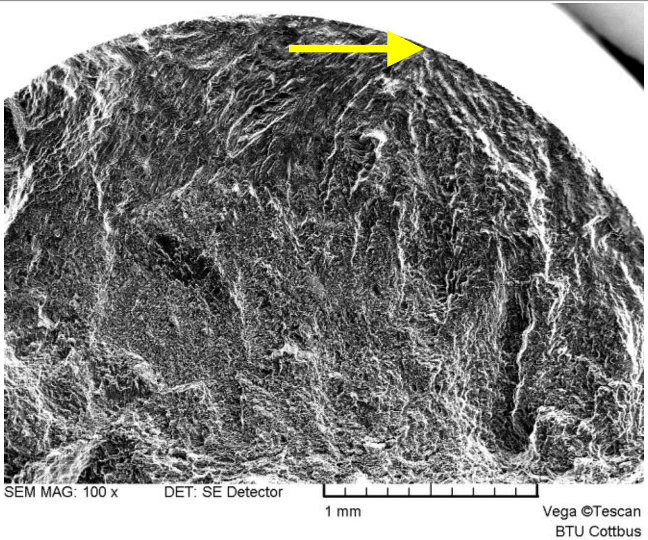


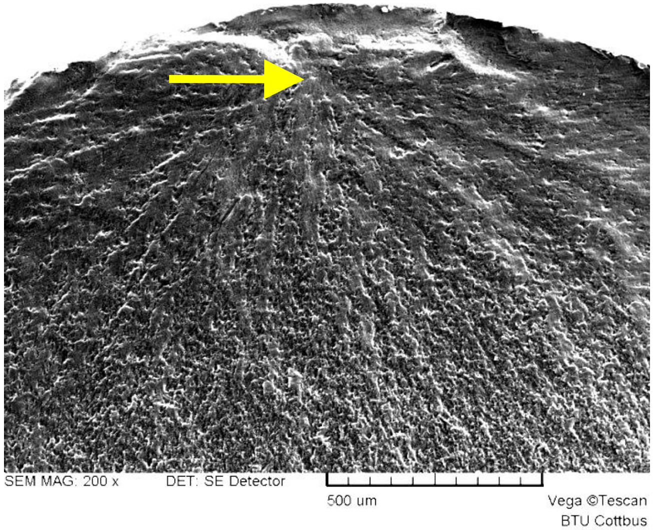
- ~ 20% improvement of fatigue strength through shot peening
- ~ 35% improvement of fatigue strength after roller burnishing

Crack initiation sites

Ti 6246

electr. polished



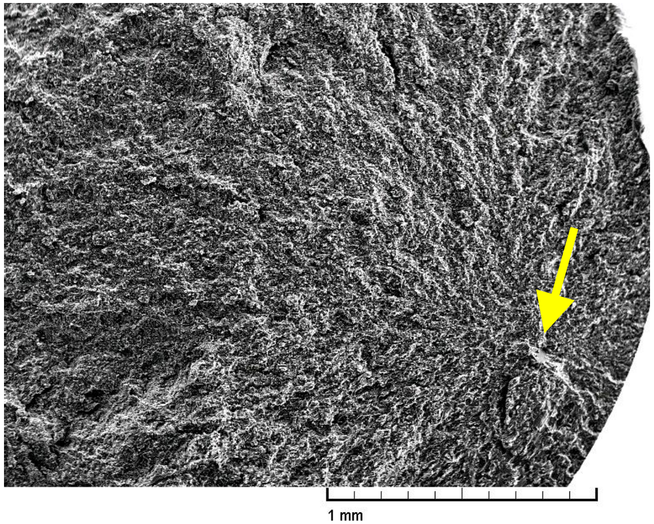


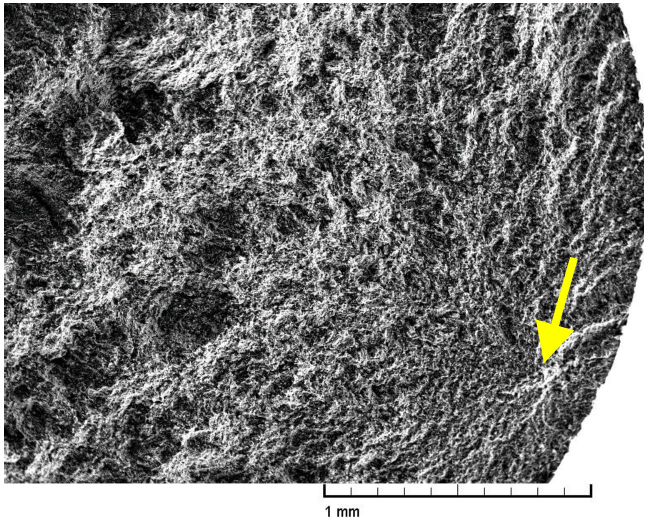
Ti 6Al 4V

shot peened

γ-TiAl

roller burnished



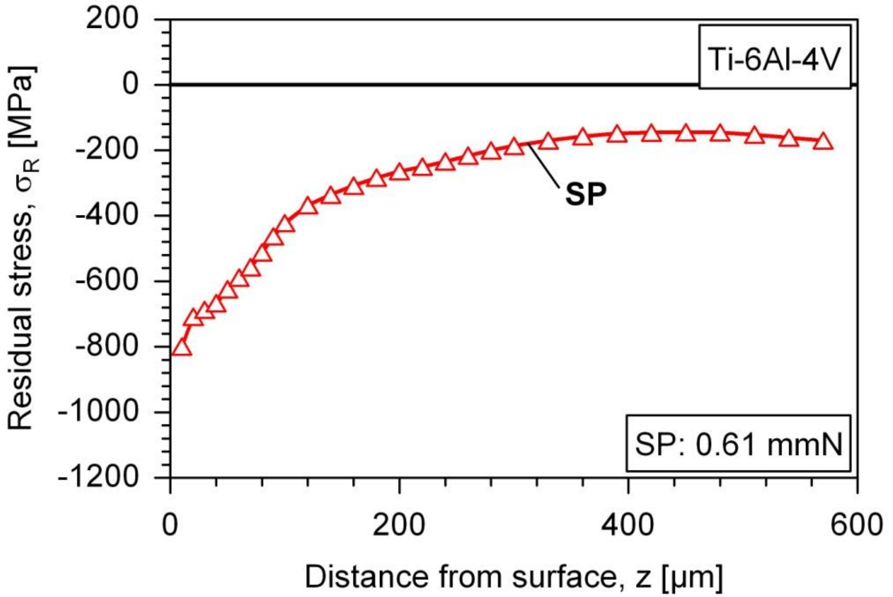


γ-TiAl

shot peened

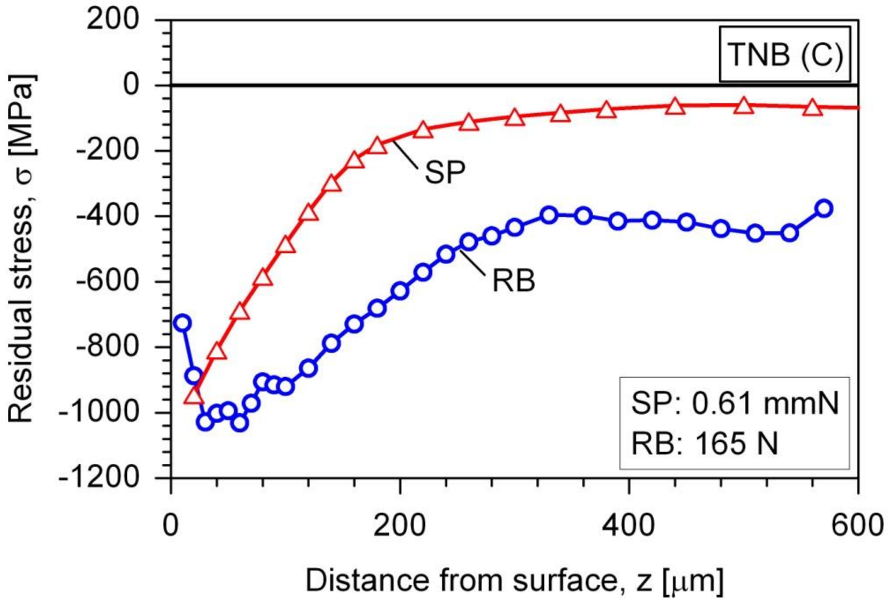
Residual stresses after mechanical surface treatment

Titanium alloy



~ 800 MPa compressive residual stresses

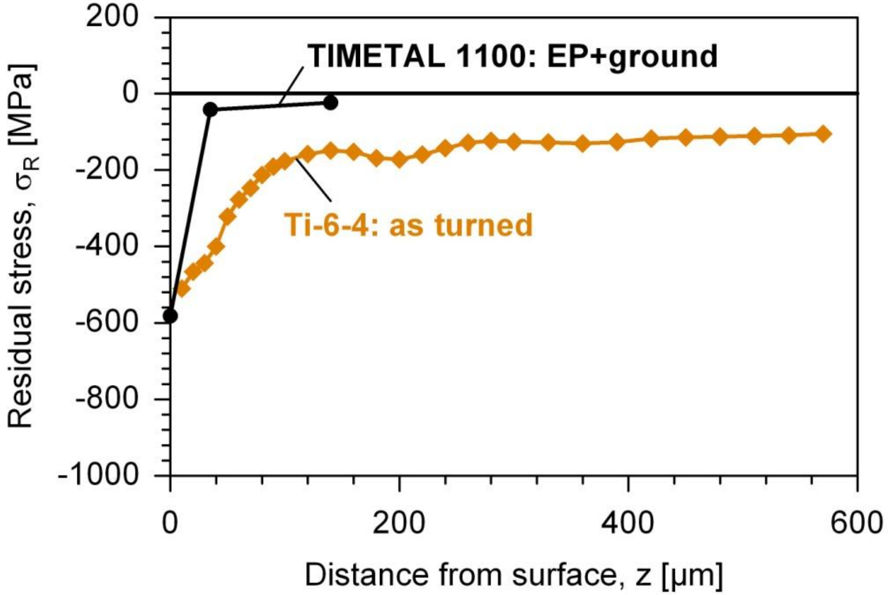
γ-Titanium aluminides



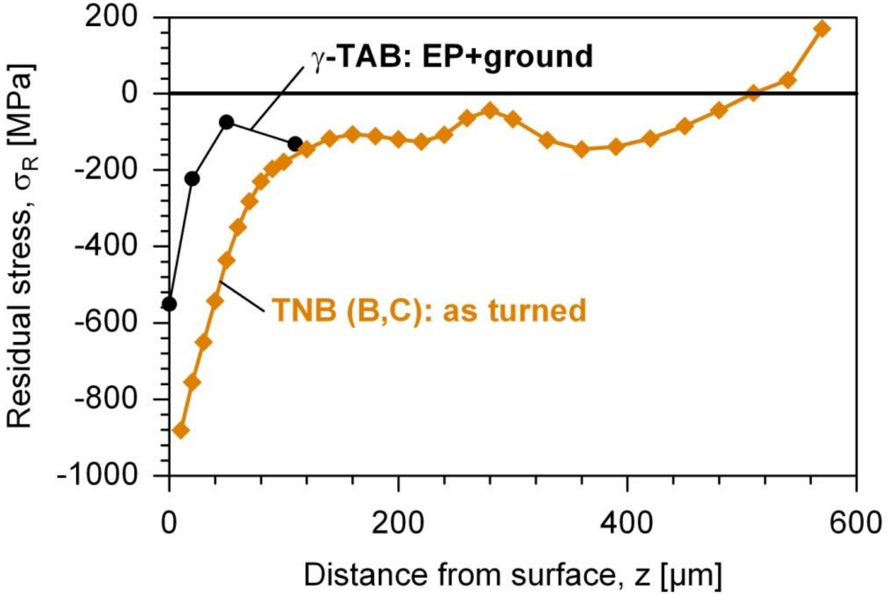
~ 1000 MPa compressive residual stresses

Residual stresses after machining

Titanium alloy



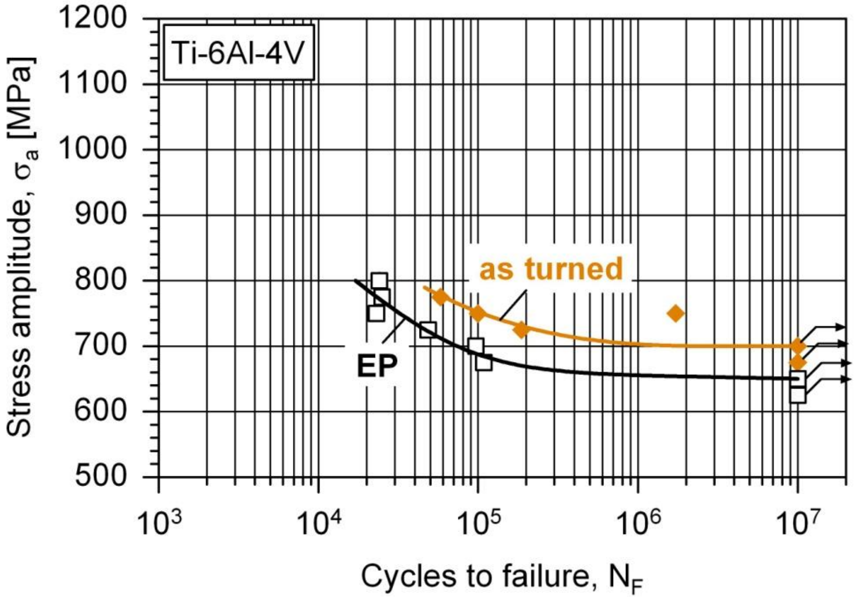
γ-Titanium aluminides



➡ Significant compressive residual stresses after machining

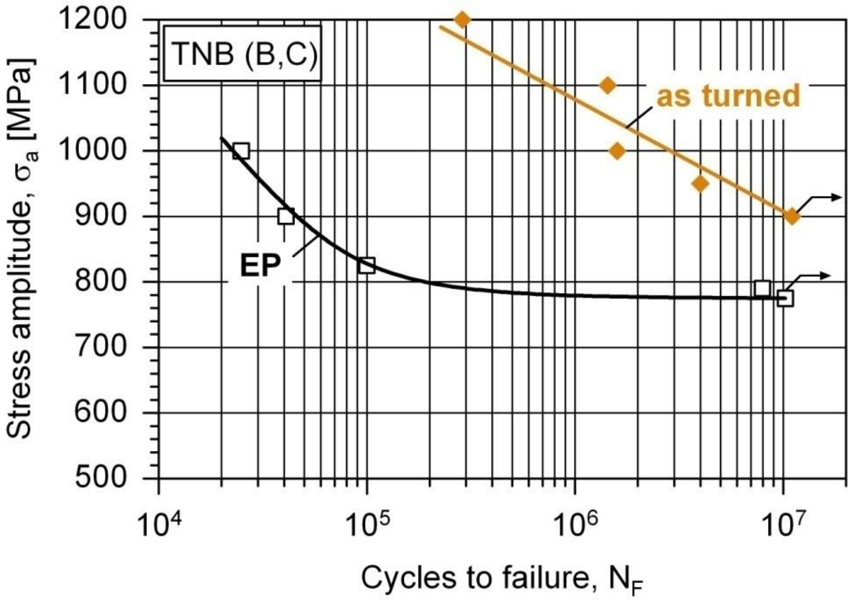
Fatigue strength after machining

Titanium alloy



~ 7% improvement of fatigue strength through turning

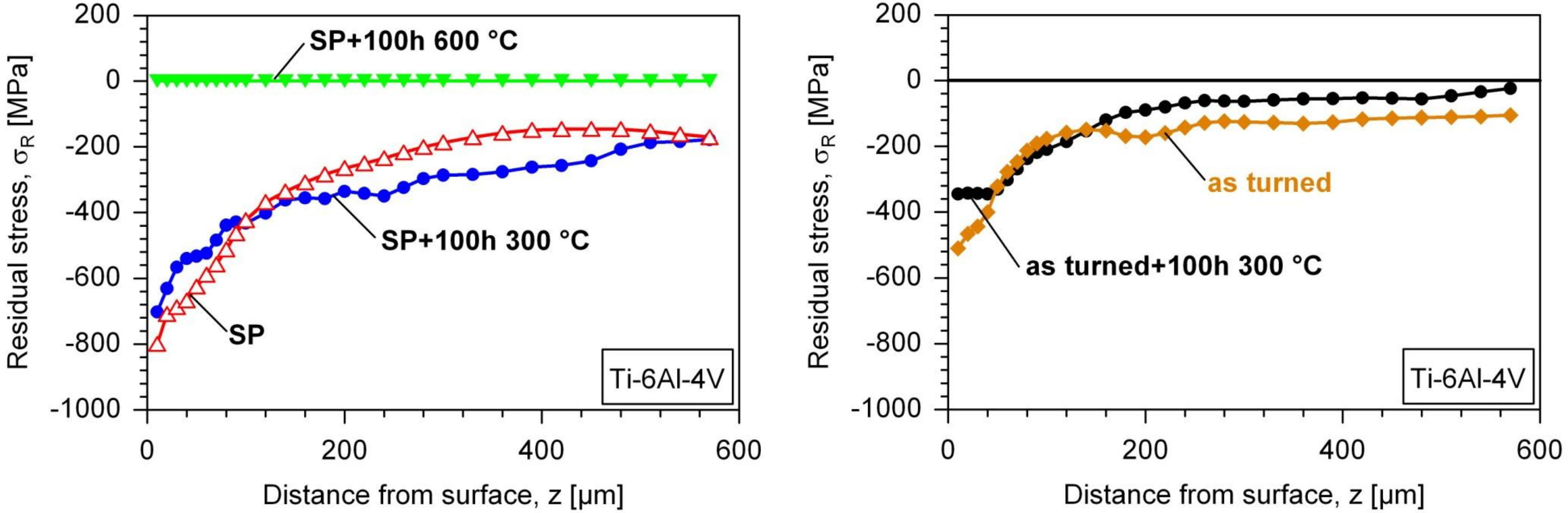
γ-Titanium aluminides



~ 16% improvement of fatigue strength through turning

Residual stresses after annealing

Titanium alloys

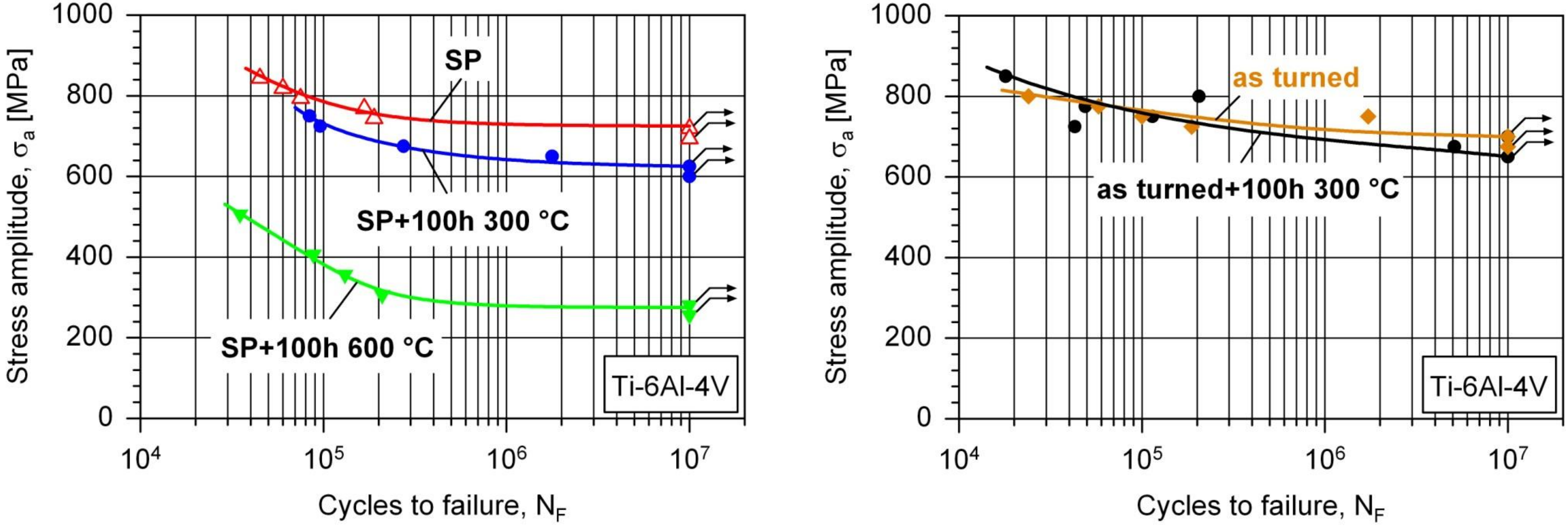


300°C : slight reduction of residual stresses

600°C : complete reduction of residual stresses

Fatigue strength after annealing

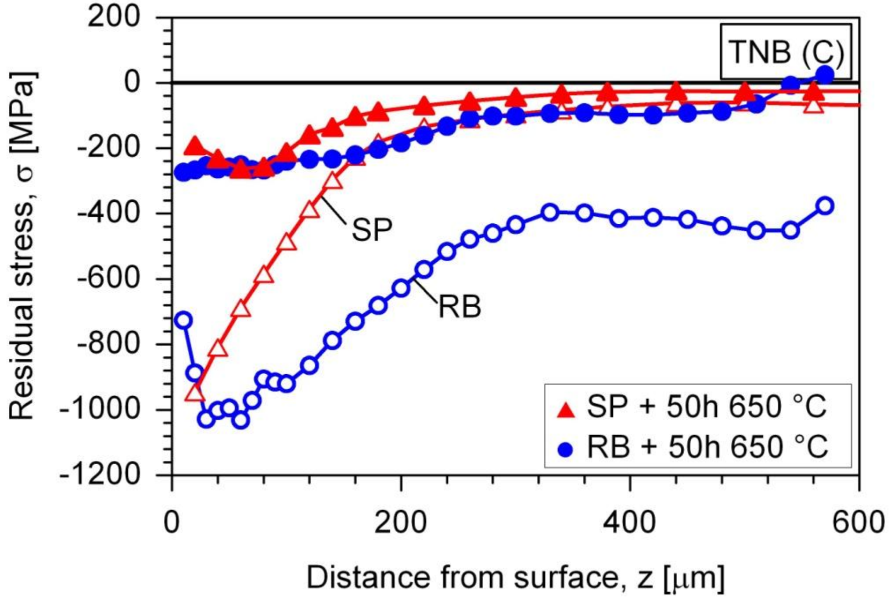
Titanium alloys

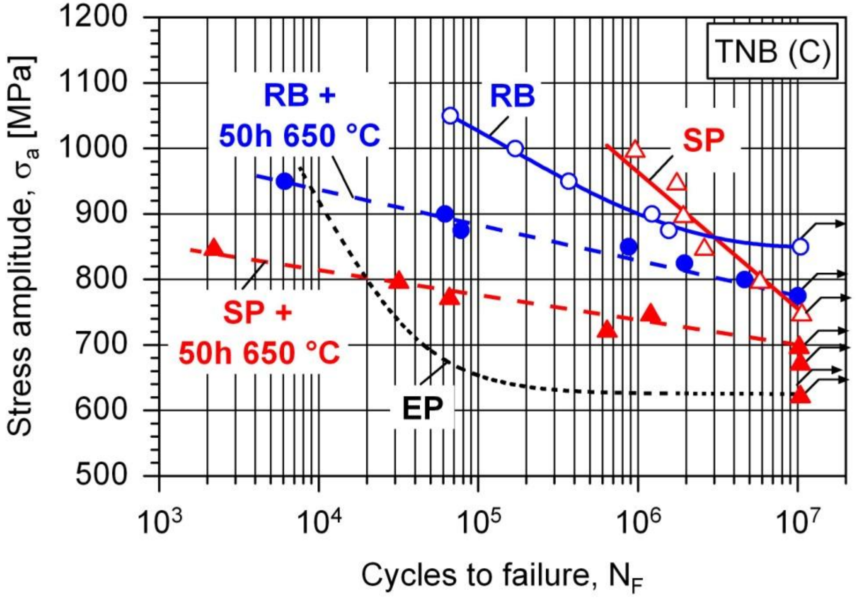


- 300°C : slight reduction of fatigue strength
- 600°C : significant reduction of fatigue strength

Residual stresses and fatigue strength after annealing

γ-Titanium aluminides

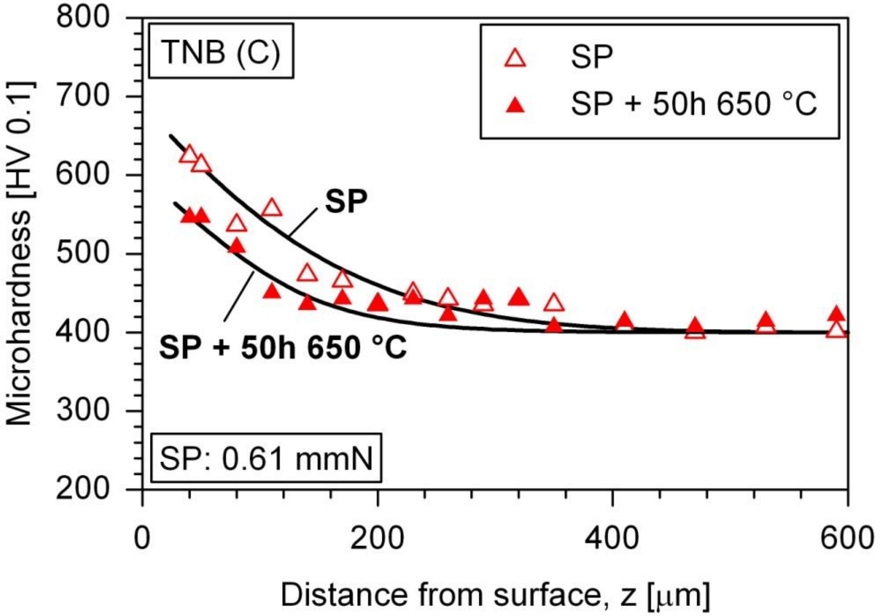


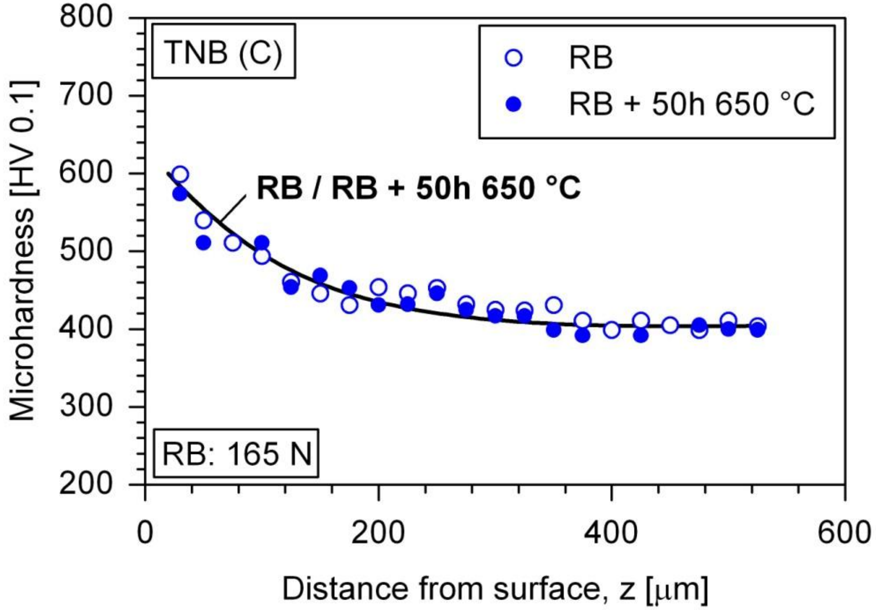


- complete reduction of residual stresses
- significant reduction of fatigue strength

Work hardening before and after annealing

γ-Titanium aluminides



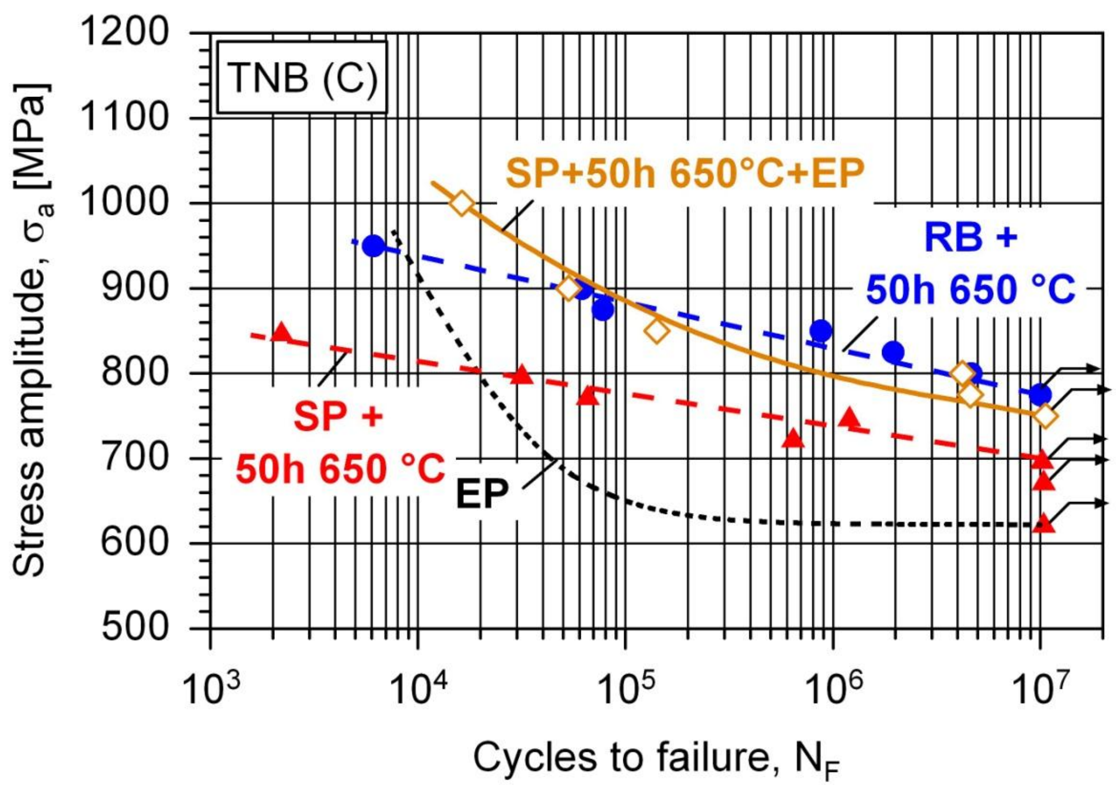


➡ High values of work hardening in the surface layer,

also after annealing

Fatigue strength after annealing

γ-Titanium aluminides



SP: 0.61 mmN
RB: 165 N

➡ additional polishing improves the fatigue strength

Conclusion

- While no effect on the tensile properties, the surface condition have a great influence on the fatigue strength of titanium-based alloys, especially at elevated temperatures.

- Compressive residual stresses, induced by mechanical surface treatments or machining, improve the fatigue strength at room temperature.

- At higher temperatures the residual stresses will be reduced or completely relieved and the fatigue strength drops.

- Work hardening improves the fatigue strength also at elevated temperatures, provided that the surface is smooth.