EFFECT OF NITROGEN ION IMPLANTATION ON THE ELAVATED TEMPERATURE FATIGUE OF SHOT-PEENED TITANIUM ALLOY

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This study focuses on the influence of nitrogen ion implantation (NII) on the medium-temperature fatigue performance of SP layer. The mean fatigue life of the SP TA15 titanium alloy was increased 27.5 times, furthermore, the median fatigue life of the-NII treated specimen at 500 ◦C for 5 h was increased by a factor of 17, compared with as-received. The SP process produced high-density dislocations and grain refinements in primary the α-phase grains. After heat exposure at 500°C/5h, dislocations and other substructures became reduced and the grains were coarsened. Furthermore, after NII treatment, the same at 500 ◦C for 5 h, a large number of TiN phases were generated so that the high-density dislocations were retained.

Keywords: Aero-engine components; fatigue performance; TA15 titanium alloy.

Introduction

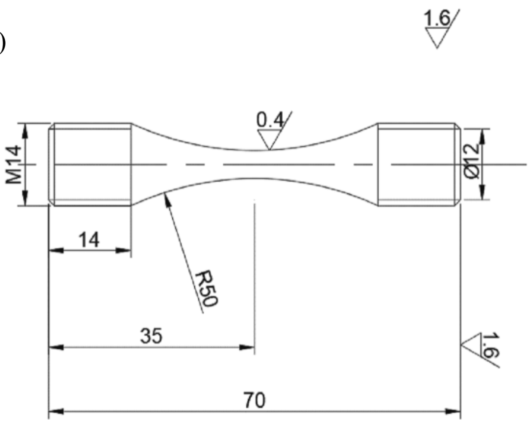
Aero-engine components, made of titanium alloy, service under alternating load and have a risk of fatigue failure. Shot peening (SP) is often applied to improve fatigue strength. However, the peening layer introduced at "room temperature" may relax at elevated temperature during the period of service. This study focuses on the influence of nitrogen ion implantation (NII) on the medium-temperature fatigue performance of SP layer.

Experimental procedure

The material was a forged TA15 titanium alloy. The SP procedure of dog-bone-shaped sample was carried out using a computer-numerical controlled (CNC) SP machine (KX-3000P) and AZB300 beads. The intensity was 0.10 mmA. After SP, two groups of samples were selected for heat exposure (SP-500) and NII with the voltage of 40kV, both at 500°C/5h (Fig. 1).

No.	Name	Status
1	AR	As-received
2	SP	Treated by SP
3	SP-500	Treated by SP, and then treated by a thermal exposure at 500 °C for 5 h
4	SP-N-500	Treated by SP, and then treated by NII at 500 °C for 5 h

(a)



(b)

Fig. 1. 4 surface states of this research (a) and the drawing of dog-bone sample (b)

Table 1. Surface rougness and stress concentration factors for the TA15 titanium alloys treated by AR, SP, SP-500, and SP-N-500

Specimens	S_a/μm	$\overline{H}$/μm	$\overline{D}$/μm	K_{st}
AR	0.629	1.47	19.66	1.137
SP	0.489	0.90	19.66	1.073
SP-500	0.495	0.87	14.96	1.099
SP-N-500	0.633	0.90	22.93	1.059

Results and discussion

Compared to grinding, spherical craters formed by SP can generate lower surface stress concentration coefficients, which is a different result from previous research (Fig. 2).

SP introduced a large amount of plastic deformation, which would recover during 500°C/4h aging; at the same time, the ion implantation process suppressed grain growth during 500 °C thermal exposure and retained the plastic deformation generated during SP (Fig. 3).

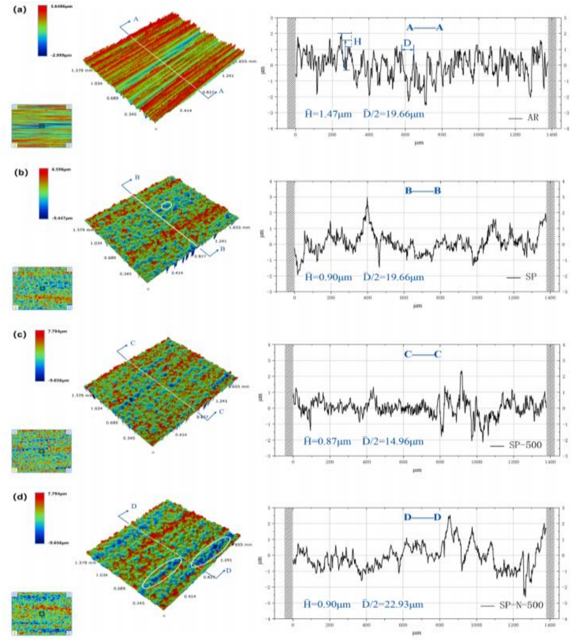


Fig. 2. Surface morphology after four states

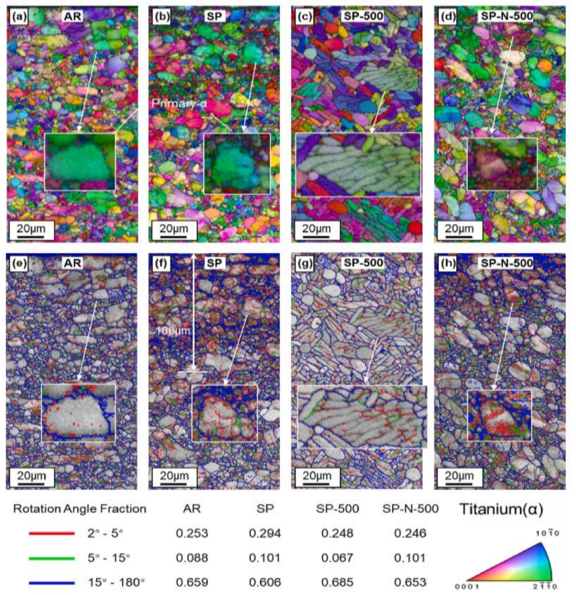


Fig. 3. Surface mmicrostructures of four states by EBSD

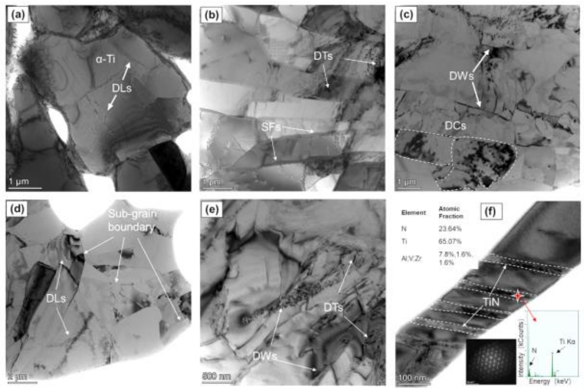


Fig. 4. Surface microsturctures of four states by TEM

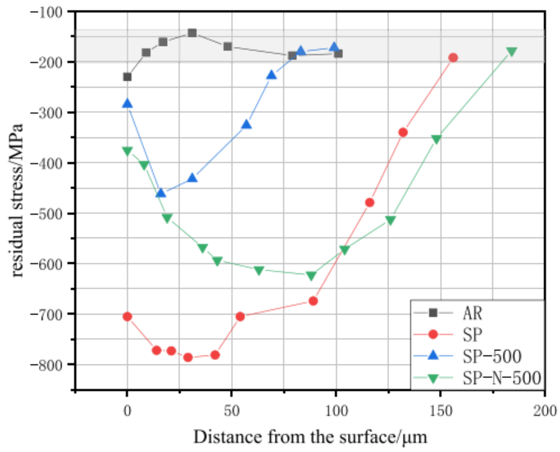


Fig. 5. Surface residual stress profiles

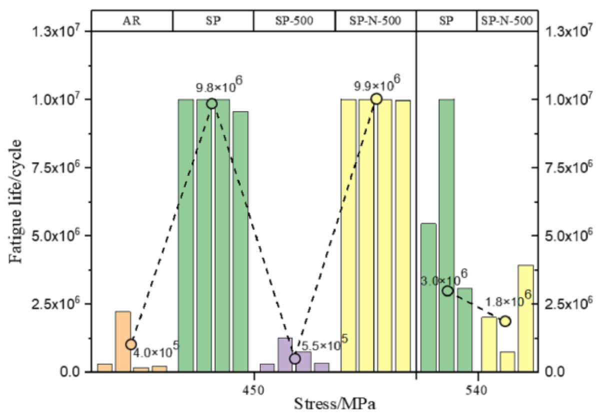


Fig. 6. the fatigue lives of the 4 surface states

SP introduced a large amount of plastic deformation, which would recover during 500°C/4h aging; while the NII process suppressed grain growth and retained the plastic deformation generated during SP (Fig. 3).

After SP, NII generated nitride hard phases and retain larger compressive residual stress at a certain depth compared with aging after SP, which were all fatigue strengthening factors.

Compared with the AR sample, the fatigue life of the SP sample increased by 23.5 times (Fig. 6). However, after 500°C/5h thermal exposure, the life is comparable to AR sample, indicating that thermal exposure eliminates the fatigue strengthening effect. When NII was also performed at 500 °C/5h, fatigue life still increased by 17 times which declare that NII improves the thermal stability of shot peening anti-fatigue effects.

Conclusion

(1) The mean fatigue life of the SP TA15 titanium alloy was increased 27.5 times, furthermore, the median fatigue life of the-NII treated specimen at 500 ◦C for 5 h was increased by a factor of 17, compared with as-received.

(2) The SP and NII reduced the local stress concentration coefficient (Kst).

(3) The SP process produced high-density dislocations and grain refinements in primary the α-phase grains. After heat exposure at 500°C/5h, dislocations and other substructures became reduced and the grains were coarsened. Furthermore, after NII treatment, the same at 500 ◦C for 5 h, a large number of TiN phases were generated so that the high-density dislocations were retained.

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