SOME PROPERTIES OF THE OVERHEATED WT3-1 TITANIUM ALLOY AFTER GLASS BEAD PEENING OR BEARING BALL PEENING

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ABSTRACT

The WT3-1 titanium alloy is used for aeroplane elements, aircraft engine parts, turbine and compressor elements. This alloy heat treatment is isothermal annealing at temperature of 900°C. The paper presents results of the tests concerning fatigue strength in relation to above allotropic temperature limit overheated and in relation to standard heat treated WT3-1 titanium alloy. Effects of glass bead peening and ball peening are compared. Fatigue strength limit at oscillatory bending was tested and, it was found that in both cases it has been improved as compared with fatigue strength limit WT3-1 titanium alloy after belt grinding.

KEYWORDS

Titanium alloy, allotropic temperature limit, annealing, bearing ball peening, glass bead peening, belt grinding, fatigue strength limit.

INTRODUCTION

The soaking heat has strong influence on properties of WT3-1 titanium alloy. If annealing temperature while heat treating or plastic forming made of this alloy machine parts will be higher than the allotropic temperature limit, then grain growth and mechanical properties change will take places too. The bigger grains the worse properties, especially fatigue strength.The tests described in this paper were realized with the aim of attaining improvement in fatigue strength limit of coarse-grained WT3-1 titanium alloy with ball peening or glass bead peening.

Bearing ball peening process can be applied to regular and irregular shape machine parts, welded joints or coated elements. This process can be also used to heat treated steels, having high hardness alloys, hard treated alloys as high-strength titanium alloys.

BEARING BALL PEENING PROCESS DESCRIPTION

The ball peening process is is based on making use of stream of small hard bearing balls, that are accelerated with compressed air and circulate in closed loop system, impacting on treated surface and causing its cold working. The process itself is effected by ejector nozzle geometry and: ball diameter, air pressure, distance from working nozzle to workpiece and peening time.

In result of the treatment, high strain hardening was achieved together with surface roughness Ra = 0,63-2,5 μm; part shape and dimensional accuracy were not effected. The treated surface have characteristic pricked surface structure and, bearing ball peening created hard surface layer with compressive residual stresses. Such surface layer condition, as it is generally known, is the best for some properties, particulary for fatigue life of machine elements, and it is why bearing ball peening process provides increase in machine parts fatigue strength (and thus much more increase in fatigue life) and in tribological wear resistance.

Ball peening process have to be realized with special machines or special ball peening heads. Developed equipment has many adventages: small overal dimensions, supply from standard compressed-air instalation, repeatability of treatment results, and possibility to treat workpieces of irregular shape and low stiffnes. The process is usefull, especially in small- and mean- lot production, for strain hardening of parts made from steel, titanium and aluminium alloys of low and medium hardness, and working in changing load conditions, and semi-fluid or mitigate slide friction working. Application of bearing ball peening process to ground surfaces may cause even elimination of subsequent polishing or belt grinding operations.

Basic adventages of bearing ball peening are as follows:

- As a working medium bearing balls dia 1 -3 mm are used, propelled at limited speed of 3-10 m/sec. As a results of that, the balls do not disintegrate, maintain their high hardness, during the process there is no dust produced, that could be pressed into the surface layer. A smooth ball surface is projected onto the treate surface in the form of scale-like indentations with radii analogous to ball radius.
- Low ball speed and their continuous recirculation cause that only a small ball charge is required and, as air supply source, a regular factory internal compressed air network can be used provided with a typical oil and moisture trapping equipment.

• Atter ricochetting, the balls fall down under gravity into the suction zone, thus eliminating ball transportion devices and making bearing ball peening machines much cheaper.

MATERIAL AND HEAT TREATMENT

The tests were carried out on specimens cuted out from 40 mm dia cylinders made of WT3-1 titanium alloy and turned on a lathe. Chemical composition and mechanical properties of WT3-1 titanium alloy are listed in table1.

Table 1. Chemical composition of the WT3-1 alloy

Al	Mo	Cr	Fe	Si	C	Ti
6,8%	2%	1,35%	0,5%	0,35%	0,06%	rest

Table 2. Mechanical properties of the WT3-1 alloy

Hardness HB [MPa]	Impact strength K [kJ/m^2]	Ultimate elongation A_5 [%]	Tensile strength R_m [MPa]
359	496	15,3	1012

This alloy standard heat treatment (isothermal annealing) was realized:
- holding at temperature of 900°C by 2 hours,
- slow cooling (into heat-treating furnace) to temperature 650°C and holding at this temperature by 2 hours and air-cooling.

EXPERIMENTAL PROCEDURE

The four-stage tests were realized as:
1. Metallographic and mechanical testing with standard measuring devices after isothermal annealing in temperature from 900°C to 1000°C with step 10°C.
2. Surface roughness and surface hardness tests were realized for samples after annealing at 900°C and treatment by three tested methods.
3. Fatigue strength tests of three lots of WT3-1 titanium alloy specimens after annealing at 900°C (standard isothermal annealing temperature), 940°C (a little below allotropic temperature limit) and 980°C (above allotropic temperature limit).
4. Ball peening or glass bead peening or belt grinding of WT3-1 titanium alloy after annealing at 900°C or overheated at 980°C and fatigue strength limit tests.

Two methods of peening: glass bead peening and bearing ball peening were tested. The test results have been compared with results for belt grinding. The belt grinding was realized with alundum grinding belts of 380 grain size. Glass bead peening treatment was performed with standard Vacu-Blast equipment AMS-243H, using 40 -150 µm diameter glass balls, two nozzles (distance from surface 120 mm, angle of impact 1,22 rad) and vacuum pressure 0,35 Mpa. The time of treatment was 32 s. Bearing ball peening treatment was performed with machines described in [1]. Individual specimens were peened with parameters listed in table 3.

Table 3. The ball peening parameters

Lot signature	Ball diameter [mm]	Time of treatment [min]	Vacuum pressure [Mpa]	Intensity (Almen test according SAE J442) [A]
A	3	15	0,18	8
B	3	15	0,10	2
C	3	15	0,14	5
D	3	45	0,18	10
E	3	10	0,30	-

Fatigue tests were realized basing on special speed-up method on electrodynamic vibrator ST 5000/300, according to methodology that have been described in [2]. All theoretical considerations are given in [3, 4]. Special test pieces are used in that method having the working surface in the shape of cylindrical section which is brought into resonance vibration motion with an amplitude assuring necessary stress level in the point of failure. A short cycle of fatigue tests in this method has been achieved due to: considerable vibrations frequency of the test piece, vibrations preferably about 1000 Hz, running the test to the first fatigue crack and its propagation to about 0,15 mm depth rather than to full test piece failure (first crack appears as drop in free vibration frequency whereas the test stand control system must automatically maintain the resonance). In this research work, fatigue strength limit can be determined by step method, basing on about 20 test pieces.

EXPERIMENTAL RESULTS

Fig. 2 shows the effect of annealing temperature changes on WT3-1 titanium alloy microstructure. Above the allotropic temperature limit, then grain growth takes pla-

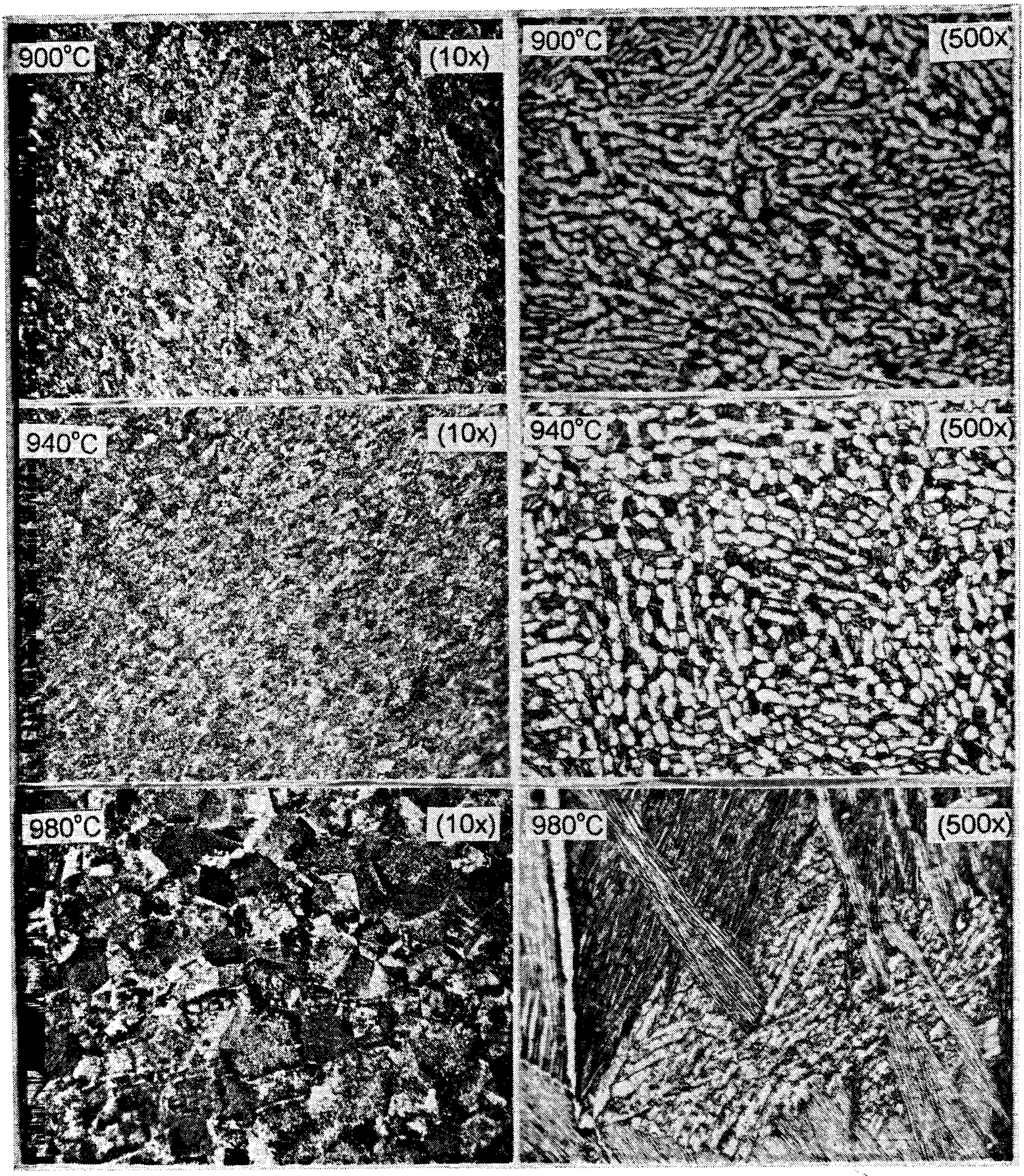

Fig. 2 . Annealing temperature influence on WT3-1 titanium alloy microstructure

ces - the grain size is bigger than after annealing at 900°C or 940°C. Fig. 3 shows analogous effect in relation to that alloy mechanical properties. Presented results show, that in results of higher (above allotropic temperature limit) annealing temperature, this alloy grain size increased and mechanical properties decreased.

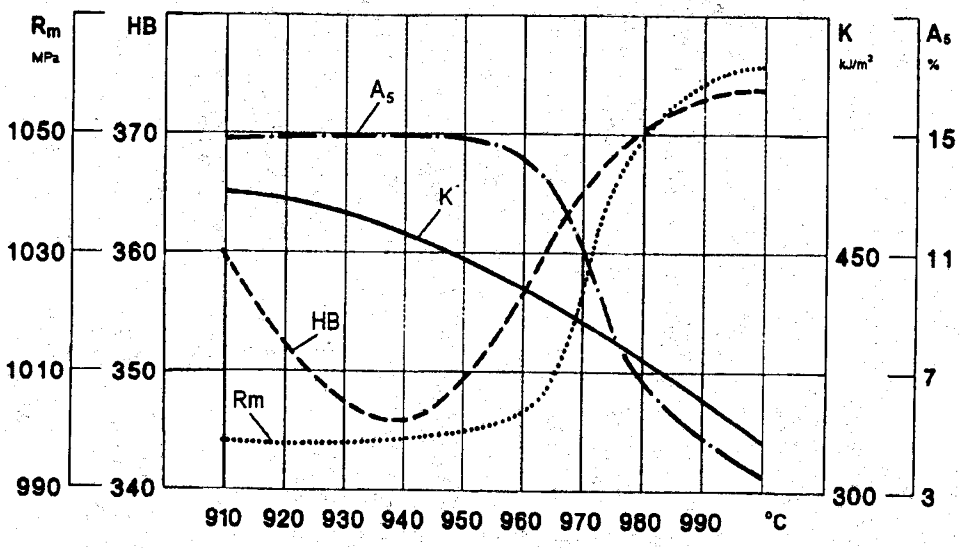

Fig. 3. The annealing temperature influence on WT3-1 mechanical properties

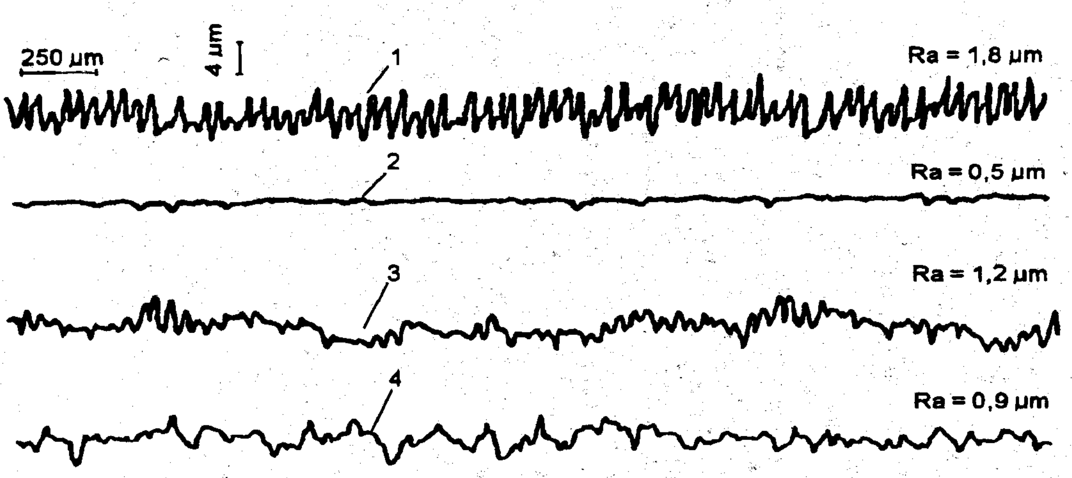

Fig. 4. Surface profilograms of WT3-1 titanium alloy specimens: 1 - turned, 2- belt ground, 3 - ball peened, 4 - glass bead peened

Presented in fig. 4 and in table 4 WT3-1 alloy surface roughness and microhardness test results (the samples after annealing at 900°C and after treating by tested methods) show, that glass bead peening and ball peening effects are similar.

Table 4. The microhardness test results

Kind of treatment	Surface micro-hardeness [μHK]	Degree of strain hardening [%]	Depth of hardening [mm]
Turning	420	12	0,25
Belt grinding	450	18	0,22
Ball peening	468	30	0,37
Glass bead peening	465	26	0,29

Table 5. Fatigue strength limit test results

No	Kind of treatment and lot signature	Fatigue limit [Mpa]	Change in relation to „1" [%]	Change in relation to „3" [%]
1	annealing at 900°C and belt grinding	525	-	-
2	annealing at 940°C and belt grinding	495	-6	-
3	annealing at 980°C and belt grinding	397	-24	-
4	annealing at 980°C and glass bead peening	594	+13	+49
5	annealing at 980°C and ball peening (A)	478	-9	+20
6	annealing at 980°C and ball peening (B)	431	-17	+8
7	annealing at 980°C and ball peening (C)	446	-15	+12
8	annealing at 980°C and ball peening (D)	438	-16	+10
9	annealing at 900°C and ball peening (E)	650	+24	-
10	annealing at 900°C and glass bead peening	745	+42	-

Presented in table 5 test results show, that made of WT3-1 titanium alloy (after standard isothermal annealing) and baering ball peened elements have fatigue strength limit about 24% better and glass bead peened about 42% better than belt ground elements.

This alloy mechanical properties become much worse after annealing at temperature above allotropic temperature limit. These properties and grain growth are interrelated because after annealing above this temperature grain size would be increased.

Overheated and belt ground elements have fatigue strength about 24% worse than standard heat treated elements. Overheated elements have fatigue strength limit about 49% better after glass bead peening, about 8 - 20% better after bearing ball peening as in compared to belt ground

CONCLUSIONS

Presented fatigue test results show a possibilities of use of the bearing ball peening and glass bead peening for fatigue strength limit increase, especially of machine parts made of WT3-1 titanium alloy..

With that methods is possible to recovery properties that have been lost in result of annealing above WT3-1 titanium alloy allotropic temperature limit.

Treatment results for both of the tested methods are similar, but bearing ball peening method is the cheaper one, because construction of relevant machine and additional equipment is very simple.

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