HEAT TREATMENT OF THE CASTED Ti6Al4V TITANIUM ALLOY

TEPELNÉ SPRACOVANIE LIATEJ TITÁNOVEJ ZLIATINY Ti6Al4V

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Abstract

The influence of the solution treatment at 1050°C, 950°C and 800°C with water or air cooling followed by aging treatment at 550°C was investigated on the specimens from Ti6Al4V model titanium alloy. After the treatments 1050°C/ water and 950°C/water α′ martensite structure was created, in the other cases a lamellar structure of α + β phases was formed.

Vplyv rozpúšťacieho žíhania pri 1050 °C, 950 °C a 800 °C s ochladzovaním do vody alebo na vzduchu s následným vytvrdzovaním pri 550 °C bol skúmaný na vzorkách z liatej modelovej zliatiny Ti6Al4V. Po spracovaní 1050 °C/ voda a 950 °C/ voda sa vytvorila α′ martenzitická štruktúra, v ostatných prípadoch vznikla lamelárna štruktúra α + β fáz.

Key words

titanium alloys, heat treatment, solution treatment, aging treatment

zliatiny titánové, spracovanie tepelné, žíhanie rozpúšťacie, vytvrdzovanie

Introduction

In the recent years the usage of titanium and titanium alloys has increased in various areas of industry (aerospace, chemistry, energetics and automobile industry). Titanium and titanium alloys are effectively applied in human orthopaedics and surgery as well. The most important characteristic features of these alloys are their low specific gravity, high strength and excellent corrosion resistance.

Except the above mentioned properties some of the titanium alloys have also high biocompatibility which gives the possibility for their application as orthopaedical alloys. The Ti6Al4V alloy belongs to one of those which are widespreadly used for implant

production [1]. Due to the high cost of titanium alloys prepared by forging and machining increased attention is paid to casting technologies which enable the manufacture of complex shapes of the implant. At the Department of Materials Engineering SUT, lead by prof. Žitňanský, series of ingots fromTi6Al4V alloys have been prepared by precision casting [2,3].

Different ways of heat treatment were carried out on the casted specimens in order to influence the microstructure as well as the properties of the Ti6Al4V alloy [4,5]. We are presenting the newest results of influencing the microstructure of casted Ti6Al4V titanium alloy by experimental heat treatment in this work.

Materials and experimental procedures

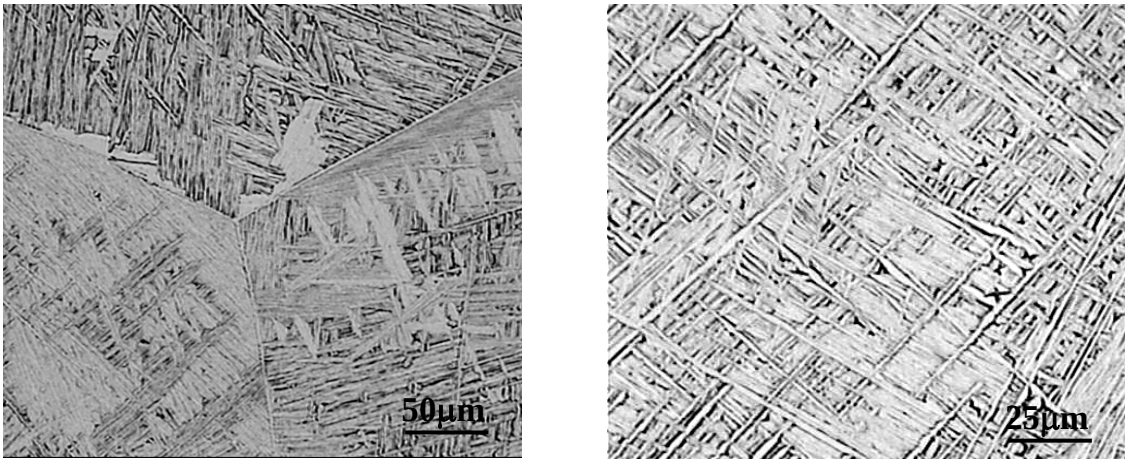
The Ti6Al4V model alloy prepared by plasma metallurgy in protective argon gas (april 2004) was tested in this work. The nominal chemical composition (in weight %) of the alloy: 6 % Al, 4 % V and the balance of Ti.

We have applied solution treatment at 1050 ^{o}C/1h, 950 ^{o}C/1h and 800 ^{o}C/1h with water and air cooling on the specimens. After the solution treatment an aging treatment at 550 ^{o}C/4h was used by air cooling. The heat treatment was carried out in the LM 212.11 induction furnace.

The specimens were prepared for the metallographical analysis by the usual process. The specimen of alloys were etched in solution:1,5 ml HF + 2 ml HNO_3 + 10 ml H_2O. The etching time was 2 - 5 s. The documentation of the microstructure was carried out by a Neophot 30 optical and a JEOL JSM 5310 scanning electron microscope. The HV 10 hardness test was realized by a Briviskop BVR 187.5H device.

Results and discussions

The microstructure of as-cast Ti6Al4V alloy is shown in Fig. 1 a and b. The structure of the alloy is two-phased, consists of α and β solid solutions. The lamellae of the α phase (shown light) are relatively regular and are mutually connected in a form of basket weave. Between these phases are thin areas of β phases (shown dark). By the boundaries of the prior β grains phase α was formed which ″delimits″ these grains (grain boundary α) .



a) b)

Fig. 1. *Initial microstructure of model Ti6Al4V alloy*
a) Character of microstructure, b) Detail of lamellar structure (α + β)

The microstructures after the solution treatment at 1050 °C are shown in the Fig. 2 and 3. As a result of fast cooling in water an acicular α′ martensite structure was formed (Fig. 2). Following the fast cooling from 1050 °C no deposition of grain boundary α was recognized. Solution treatment at 1050 °C by air cooling lead to the typical lamellar α + β structure with a grain boundary α on the prior β grains (Fig. 3).

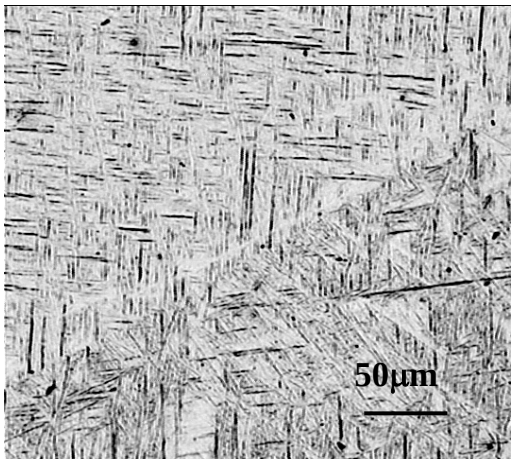


Fig. 2. *Ti6Al4V, 1050 °C/1h/water*

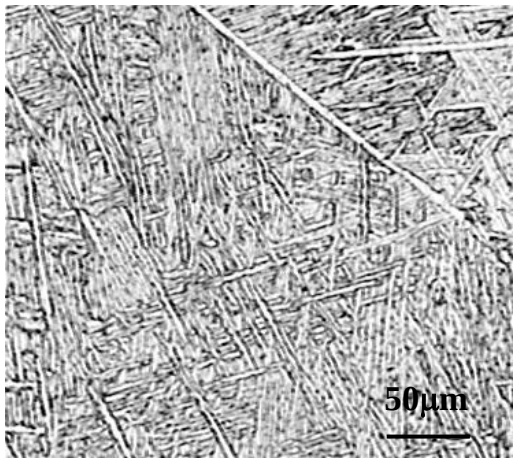


Fig. 3. *Ti6Al4V, 1050 °C/1h/air*

Cooling in water from 950 °C produces a microstructure which consist of acicular α′ martensite and primary α (Fig. 4). On the borders of prior β grains an α grain boundary are formed. The microstructure of Ti6Al4V alloy after the solution treatment at 950 °C/air is shown in Fig. 5. The structure contains a lamellar mixture of α + β phases, primary α and grain boundary α. Considering the low cooling rate no α′ martensite was formed.

The microstructures after the solution treatment at 800 °C are shown in the Fig. 6 and 7.

Following the water cooling regular lamellae forms of phase α (Fig. 6) can be recognized, while following the air cooling more coarse lamellar structure was formed (Fig. 7). The metallographycal investigation showed that no α′ martensite phase was formed after the solution treatment from 800 °C by cooling in water. As a result of fast cooling a metastable β phase with a certain level of oversaturation could occur.

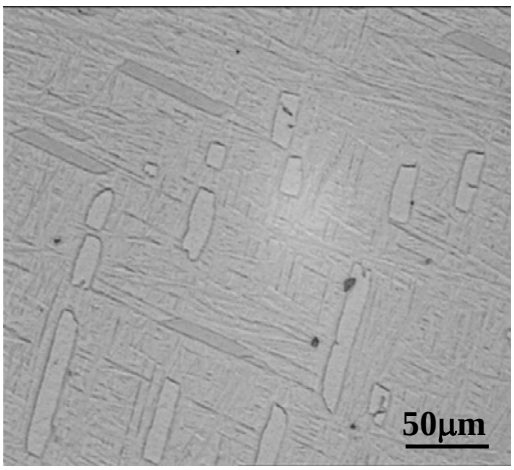


Fig. 4. *Ti6Al4V, 950 °C/1h/water*

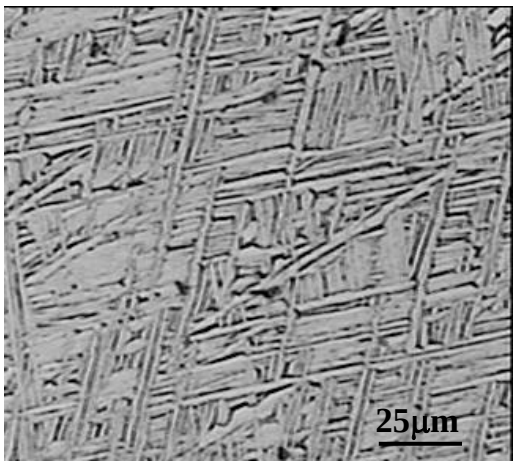


Fig. 5. *Ti6Al4V, 950 °C/1h/air*

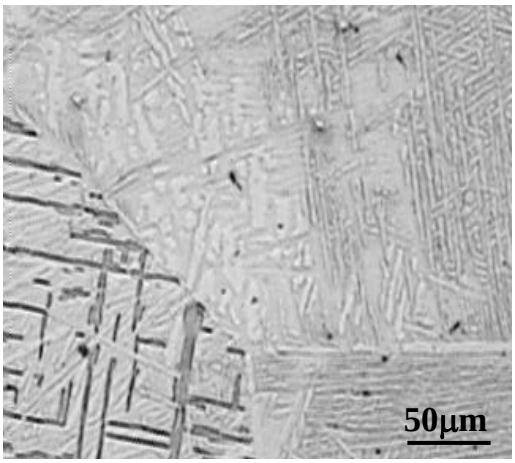


Fig. 6. *Ti6Al4V, 800 °C/1h/water*

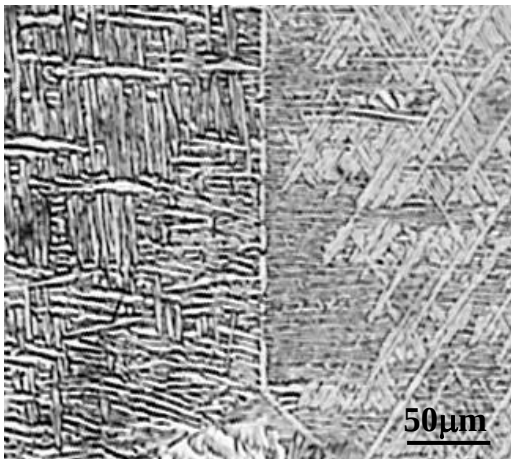


Fig. 7. *Ti6Al4V, 800 °C/1h/air*

The view of the developed microstructure after the applied processes of solution treatment of casted Ti6Al4V model titanium alloy is being shown schematically in Fig. 8.

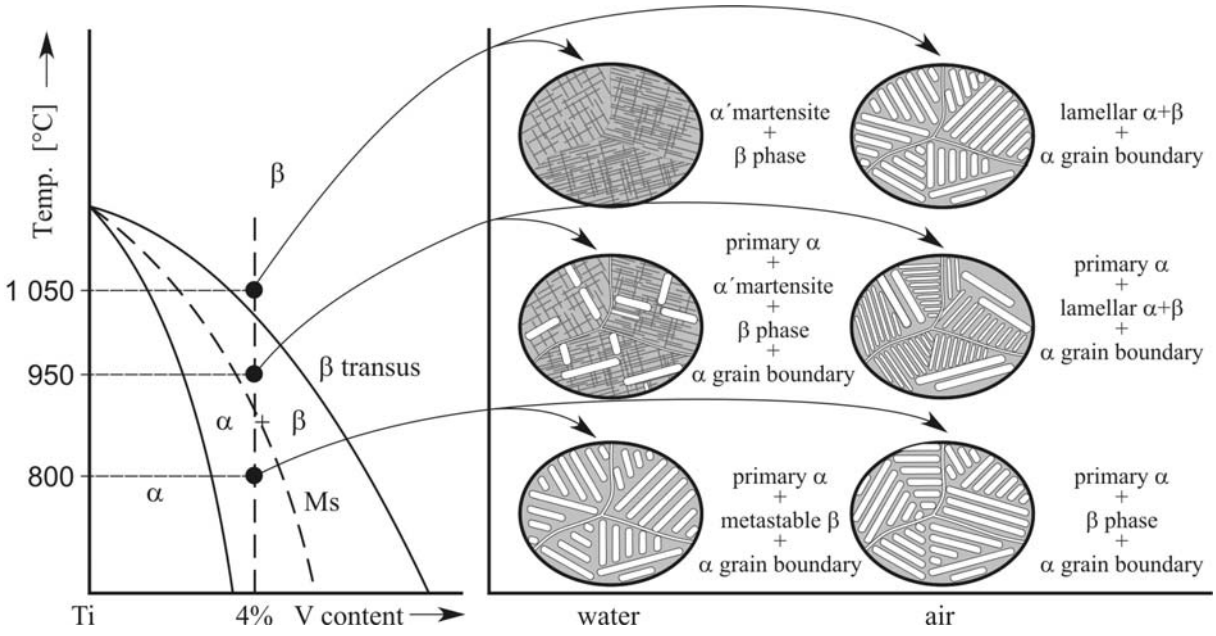


Fig . 8. *Schematic representation of microstructures developed after solution treatment of casted Ti6Al4V model titanium alloy*

After each solution treatment process an aging treatment at 550 °C was carried out by air cooling. The characteristic feature of the microstructure which was formed after the solution treatment basically remained even after this treatment. In the Fig. 9 is shown microstructure of the alloy after the whole heat treatment process 1050 °C/water + 550 °C. The acicular-like structure was clearly preserved.

The microstructures after the applied heat treatment processes were observed also by scanning electron microscopy (SEM).The SEM analyses verified the results obtained by optical microscopy. A detailed view to the lamellar areas of α phase with narrow areas of β phase after treatment at 1050 °C/air + 550 °C are shown in Fig 10.

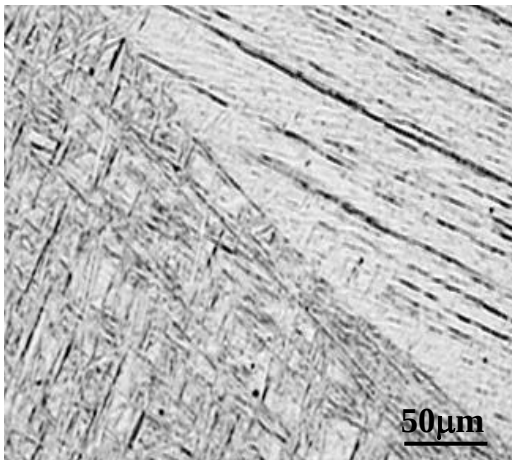


Fig. 9. *Ti6Al4V, 1050 °C/1h/water + 550 °C/4h*

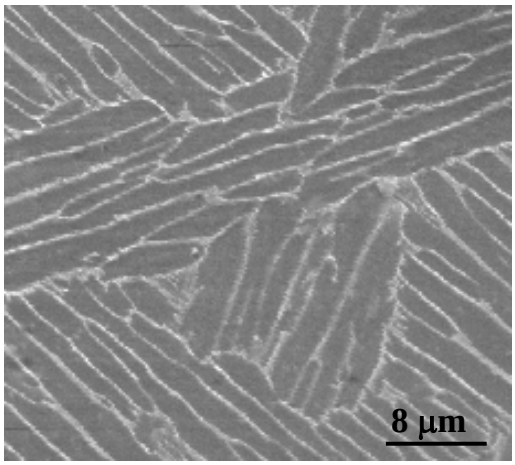


Fig. 10*. Ti6Al4V, 1050 °C/1h/air + 550 °C/4h, SEM*

The results of hardness tests are shown in Table 1. The growth of hardness was more significant in the case of cooling into water from the solution temperature. After every complete heat treatment process (solution and aging treatment) a growth of hardness was observed in comparison with the initial as-cast state. The highest hardness was noticed after the treatment at 1050 °C/water + 550 °C. The growth of hardness represented above 100 HV in this case opposed to the initial state of alloy.

THE INFLUENCE OF HEAT TREATMENT ON THE HARDNESS OF THE TI6AL4V ALLOY Table 1

Titanium alloy Ti6Al4V	**Solution treatment**	1050 °C/ 1h/water	1050 °C/ 1h/air	950 °C/ 1h/water	950 °C/ 1h/air	800 °C/ 1h/water	800 °C/ 1h/air
	Hardness HV 10	405	320	395	311	344	319
Hardness in as-cast condition 312 HV 10	**Solution treatment + aging**	1050 °C/ 1h/water + 550 °C/4h	1050 °C/ 1h/air + 550 °C/4h	950 °C/ 1h/water + 550 °C/4h	950 °C/ 1h /water + 550 °C/4h	800 °C/ 1h /water + 550 °C/4h	800 °C/ 1h /water + 550 °C/4h
	Hardness HV 10	428	338	414	352	368	346

It seems that for the increasing of hardness the creation of martensite structure α′ and its decomposition is more important than the formation of metastable β solid solution and its decomposition during the aging treatment. The results obtained by heat treatment of the casted Ti6Al4V model alloy are being used at planning the heat treatment parameters of specimens for investigating the mechanical properties of this alloy.

Conclusions

The results obtained from experimental heat treatment of casted Ti6Al4V model alloy show that an α′ martensitic structure is formed after water cooling from the solution treatment at 1050 ^{o}C. After the water cooling from 800 ^{o}C only an α phase lamellar structure was created in the untransformed β phase. Martensite α′ structure did not appear. After water cooling from 950 ^{o}C α′ martensite structure with primary α phase was formed. Air cooling from each solution temperature lead to lamellar structure of α+β phases. The character of the formed microstructures has not changed basically after the aging treatment at 550 ^{o}C. The highest growth of hardness compared with the initial hardness was detected after the heat treatment at 1050 ^{o}C/1h/water + 550 ^{o}C/4h.

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