The Effect of Microstructure on Hot Plasticity of α+β Titanium Alloys
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Rzeszow University of Technology, Poland

ABSTRACT
Hot deformation behaviour of two-phase titanium alloys is determined by the type of microstructure developed in heat treatment and plastic deformation processes. The influence of initial and final heat treatment parameters and degree of plastic deformation on hot plasticity of Ti-6Al-4V and Ti-6Al-2Mo-2Cr alloys is discussed in the paper. Tested alloys were hot deformed at the temperature range of 1123÷1323K and at the strain rate from 0.01 to 0.5 s⁻¹ (including superplastic conditions). Microstructural investigations were carried out using light microscopy and TEM techniques. Stereological parameters of microstructure before and after hot deformation were determined. Evaluation of their influence on hot plasticity (maximum flow stress $\sigma_{pm}$ and relative elongation $A$) of selected two-phase titanium alloys was performed.

INTRODUCTION
Two phase titanium alloys most often are hot deformed, mainly by open die or die forging. Achievement of desired mechanical properties is related to development of proper microstructure in plastic working and heat treatment processes. Irreversible microstructural changes caused by deformation in $\alpha+\beta\leftrightarrow\beta$ phase transformation range quite often can not be eliminated or decreased by heat treatment and therefore required properties of products can not be achieved [1-3].

During hot working of titanium alloys several factors make difficult or even preclude obtaining products having adequate microstructure and properties i.e.: high chemical affinity to oxygen, low thermal conductivity and high heat capacity and significant dependence of plastic flow resistance on strain rate [5,7]. Differences in temperature across the material volume, which result from various deformation conditions (local strain and strain rate) and physical properties of titanium lead to formation of zones having various phase composition (equilibrium $\alpha$ and $\beta$ phases, martensitic phases $\alpha'$ ($\alpha''$)), morphology (equiaxial, lamellar, bi-modal) and dispersion (fine- or coarse-grained) and therefore various mechanical properties [2,4].

Obtaining demanded microstructure of Ti-6Al-4V titanium alloy using plastic deformation in the $\alpha+\beta\leftrightarrow\beta$ phase transformation range necessitate proper conditions selection taking into consideration plastic deformation, phase transformation, dynamic recovery and recrystallization effects [4-6]. Increase of plastic deformation effects (grain refinement) can be obtained by including preliminary heat treatment in thermomechanical process. Final heat treatment operations are usually applied for stabilization of microstructure (they restrict grain growth) [7].

Previous investigations on effect of thermomechanical process conditions on superplasticity of Ti-6Al-4V [8,9] showed that the proper selection of preliminary treatment parameters considerably enhances superplastic deformation of tested alloys which is related to initial microstructure and its changes during deformation [10].

In the paper the effect of microstructure developed in various thermomechanical processes on hot deformation behaviour of Ti-6Al-4V and Ti-6Al-2Mo-2Cr titanium alloys was examined.

EXPERIMENTAL PROCEDURE
Martensitic two-phase Ti-6Al-4V and Ti-6Al-2Mo-2Cr titanium alloy bars with diameter of 16 mm were examined. Chemical composition of tested alloys was shown in Tab. 1.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Al</th>
<th>V</th>
<th>Mo</th>
<th>Cr</th>
<th>Fe</th>
<th>Si</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti-6Al-4V</td>
<td>6.78</td>
<td>4.38</td>
<td>-</td>
<td>-</td>
<td>0.18</td>
<td>0.33</td>
<td>bal.</td>
</tr>
<tr>
<td>Ti-6Al-2Mo-2Cr</td>
<td>6.87</td>
<td>-</td>
<td>3.16</td>
<td>1.57</td>
<td>0.45</td>
<td>0.65</td>
<td>bal.</td>
</tr>
</tbody>
</table>

Critical temperatures of $\alpha+\beta\leftrightarrow\beta$ phase transformation were determined on BÄHR 805 A/D dilatometer using 10⁴K/min heating and cooling rate. On the basis of dilatomeric results and previous investigations conditions of heat treatment and plastic deformation were defined and two schemes of thermomechanical processing were worked out, called in the paper TMP-I and TMP-II (Fig. 1). Preliminary heat treatment – quenching – was carried out from the temperature of 1323K – above the finish temperature of $\alpha+\beta\leftrightarrow\beta$ phase transformation. Plastic
deformation in the $\alpha + \beta \rightarrow \beta$ phase transformation range (1173K) was performed in industrial conditions (WSK “PZL-Rzeszow” S.A.) using open die forging process with forging reduction ($\varepsilon$) of about 20 and 50% (Fig. 1).

![Fig. 1. Schemes of thermomechanical processing of Ti-6Al-4V alloy with forging reduction $\varepsilon = 20\%$ (a) and $\varepsilon = 50\%$ (b) (WQ - water quenching).](image)

Light microscope (LM) Nikon Epiphot 300 equipped with digital camera Nikon DS-1U and transmission electron microscope (TEM) Tesla BS540 and JEOL JEM-2100 were employed for microstructural observation. Evaluation of stereological parameters of microstructural constituents was performed on longitudinal etched microsections using quantitative metallography methods and image analysis software Aphelion 3.2. Following parameters were determined:

- Ti-6Al-4V with grained initial microstructure: grain size of $\alpha$ phase expressed by length of sides of rectangular circumscribed on grain section $a_{\alpha}$ and $b_{\alpha}$, elongation factor of $\alpha$ phase grains $f_{\alpha}$, and volume fraction of $\alpha$ phase $V_{\alpha}$.
- Ti-6Al-2Mo-2Cr with lamellar microstructure: grain size of primary $\beta$ phase expressed by length of sides of rectangular circumscribed on grain section $a_{\beta}$ and $b_{\beta}$, elongation factor of primary $\beta$ phase grains $f_{\beta}$, and size of the colony of parallel $\alpha$-lamellae $R$. Thickness of $\alpha$-lamellae and volume fraction of $\alpha$ phase $V_{\alpha}$.

Hot deformation tests in vacuum conditions ($p = 0.005$ Pa) were carried out on universal hydraulic testing machine Instron 8801 at the temperature of 1123K and 1198K below and within the temperature range of $\alpha + \beta \rightarrow \beta$ phase transformation, respectively. The strain rates $\dot{\varepsilon} = 1\cdot10^{-2}$, $1\cdot10^{-1}$ and $5\cdot10^{-1}$ s$^{-1}$ were applied. Round specimens having diameter of 6 mm and gauge length of 8 mm were used. The maximum flow stress $\sigma_{\text{pm}}$ and relative elongation $A$ were determined.

**RESULTS AND DISCUSSION**

Dilatometric examination revealed different critical temperatures of $\alpha + \beta \rightarrow \beta$ phase transformation in tested titanium alloys – the temperature range of phase transformation was considerably wider in Ti-6Al-2Mo-2Cr alloy (Tab. 2).

<table>
<thead>
<tr>
<th>Critical temperatures of $\alpha + \beta \rightarrow \beta$ phase transformation of as received titanium alloys</th>
<th>Alloy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of $\alpha + \beta$</td>
<td>Ti-6Al-4V</td>
<td>1167</td>
</tr>
<tr>
<td>End of $\alpha + \beta$</td>
<td>Ti-6Al-2Mo-2Cr</td>
<td>1076</td>
</tr>
<tr>
<td>Start of $\beta \rightarrow \alpha$</td>
<td>1252</td>
<td></td>
</tr>
<tr>
<td>End of $\beta \rightarrow \alpha + \beta$</td>
<td>1242</td>
<td></td>
</tr>
<tr>
<td>End of $\beta \rightarrow \beta + \alpha$</td>
<td>1150</td>
<td></td>
</tr>
<tr>
<td></td>
<td>924</td>
<td></td>
</tr>
</tbody>
</table>

Microstructure of as-received Ti-6Al-4V alloy is composed of globular, fine $\alpha$ grains and $\beta$ phase in the form of thin layers separating $\alpha$ grains (Fig. 2a). Quenching of Ti-6Al-4V alloy from the $\beta$ phase temperature range leads to formation of microstructure composed solely of martensitic $\alpha''$ phase (Fig. 2b).

Microstructure after following plastic deformation in the $\alpha + \beta \rightarrow \beta$ range with forging reduction of about 20% (TMP-I) and 50% (TMP-II) contains elongated and deformed grains of primary $\beta$ phase in the matrix of $\beta$ transformed phase containing fine globular grains of $\alpha$ secondary phase (Fig. 2c,d). Higher degree of initial deformation leads to obtaining finer microstructure containing more elongated $\alpha$ grains $f_{\alpha} = 16$ for $\varepsilon = 20\%$ and $f_{\alpha} = 21.1$ for $\varepsilon = 50\%$. The larger volume fraction of $\alpha$ phase was also found (Tab. 3.).

<table>
<thead>
<tr>
<th>Condition of Ti-6Al-4V alloy</th>
<th>$V_{\alpha}$ [%]</th>
<th>$a_{\alpha}$</th>
<th>$b_{\alpha}$</th>
<th>$f_{\alpha}$</th>
<th>$\tau_{\alpha}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>As-received</td>
<td>62</td>
<td>4.1</td>
<td>5.3</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td>TMP-I processed</td>
<td>59</td>
<td>51.3</td>
<td>3.2</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>TMP-II processed</td>
<td>79</td>
<td>23.2</td>
<td>1.1</td>
<td>21.1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition of Ti-6Al-2Mo-2Cr alloy</th>
<th>$V_{\alpha}$ [%]</th>
<th>$a_{\beta}$</th>
<th>$b_{\beta}$</th>
<th>$f_{\beta}$</th>
<th>$\tau_{\beta}$</th>
<th>$R$ [μm]</th>
<th>$g$ [μm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>As-received</td>
<td>34</td>
<td>137</td>
<td>42</td>
<td>3.26</td>
<td>12</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>TMP-I processed</td>
<td>34</td>
<td>137</td>
<td>42</td>
<td>3.26</td>
<td>12</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>TMP-II processed</td>
<td>40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Microstructure of as-received Ti-6Al-2Mo-2Cr alloy is composed of colonies of parallel $\alpha$-lamellae enclosed in primary $\beta$ phase grains (Fig. 3a). Solution heat treatment leads to formation of microstructure composed of martensitic $\alpha''$ phase, similarly to Ti-6Al-4V alloy (Fig. 3b). Microstructure after thermomechanical processes (TMP-I and TMP-II) contains fine, elongated grains of $\alpha$ phase in the matrix of $\beta$ transformed phase (Fig. 2c,d). In contrary to Ti-6Al-4V alloy primary $\beta$ phase grain boundary was
observed. Higher degree of initial deformation in thermomechanical process leads to obtaining finer microstructure and larger volume fraction of α phase (Tab. 3).

Fig. 2. Microstructure (DIC) of Ti-6Al-4V alloy before thermomechanical processing (a), after quenching from the β phase range (b) and after deformation in the α+β→β range with forging reduction of 20 (c) and 50% (d).

TEM examination of Ti-6Al-4V alloy revealed fragmentation of elongated α phase (Fig. 4a) and presence of globular secondary α grains in the β transformed matrix (Fig. 4b) after TMP-I thermomechanical processing. Higher dislocation density in elongated α grains was observed after TMP-II processing (larger forging reduction) (Fig. 5a,b).

Fig. 3. Microstructure (DIC) of Ti-6Al-2Mo-2Cr alloy before thermomechanical processing (a), after quenching from the β phase range (b) and after deformation in the α+β→β range with forging reduction of 20 (c) and 50% (d).

In Ti-6Al-2Mo-2Cr alloy after TMP-I processing dislocations were observed mainly near grain boundaries (Fig. 6a). It was found that the secondary α phase in β transformed matrix occurs in lamellar form (Fig. 6b). Higher degree of deformation in TMP-II process led to higher dislocation density in α phase grains (Fig. 7a) and fragmentation of elongated α grains (Fig. 7b).

In Ti-6Al-2Mo-2Cr alloy higher volume fraction of β phase (Tab. 3) was found than in Ti-6Al-4V alloy which can be explained by higher value of coefficient of β phase stabilisation $K_β$ [11].
Fig. 4. Microstructure (TEM) of Ti-6Al-4V alloy after TMP-I process: fragmentation of $\alpha$ phase (a), globular secondary $\alpha$ phase grain (b)

Fig. 5. Microstructure (TEM) of Ti-6Al-4V alloy after TMP-II process: high dislocation density in $\alpha$ grains

Fig. 6. Microstructure (TEM) of Ti-6Al-2Mo-2Cr alloy after TMP-I process: dislocation networks in $\alpha$ grains (a), lamellae of secondary $\alpha$ phase in the $\beta$ transformed matrix (b)

Fig. 7. Microstructure (TEM) of Ti-6Al-2Mo-2Cr alloy after TMP-II process: dislocations in $\alpha$ grains (a), subgrains in $\alpha$ phase (b)

On the basis of tensile tests at 1123K and 1198K (below and within the temperature range of $\alpha+\beta\rightarrow\beta$ phase transformation, respectively) on thermomechanically processed Ti-6Al-4V and Ti-6Al-2Mo-2Cr alloys it was found that the maximum flow stress $\sigma_{pm}$ decrease with increase of hot deformation temperature and rise of strain rate (Fig. 8).

It was found that the maximum flow stress $\sigma_{pm}$ determined in tensile test is higher at lower test temperature 1123K for the strain rate range applied (Fig. 8). There is no significant effect of degree of initial deformation (forging) of two tested alloys on $\sigma_{pm}$ value for both 1123K and 1198K test temperature (Fig. 8).
The relative elongation $A$ of hot deformed Ti-6Al-4V and Ti-6Al-2Mo-2Cr titanium alloys decrease with the increasing strain rate $\varepsilon$ in whole used range (Fig. 9). For higher $\varepsilon$, the influence of forging reduction $\varepsilon$ in thermomechanical processing and tensile test temperature is very slight. Considerable differences are visible for $\varepsilon = 1 \cdot 10^{-2}$ s$^{-1}$ where the maximum $A$ value was achieved for both alloys deformed at 1123K. After thermomechanical processing TMP-II ($\varepsilon \approx 50$%) alloys exhibit maximum elongations, typical for superplastic deformation (Fig. 9). It seems that higher grain refinement obtained in thermomechanical process enhanced hot plasticity of two-phase titanium alloys deformed with low strain rates. Similar behaviour was observed in previous researches on superplasticity of thermomechanically processed Ti-6AI-4V alloy [8-10]. It was found that fragmentation and globularization of elongated $\alpha$ phase grains during initial stage of hot deformation restricted grain growth and resulted in higher values of strain.

CONCLUSIONS

1. Proposed thermomechanical processing causes transformation of microstructure of Ti-6Al-4V and Ti-6Al-2Mo-2Cr alloys from globular and lamellar respectively to highly deformed containing distorted and elongated $\alpha$ grains.

2. Increase of degree of initial deformation (forging) leads to formation of more elongated and refined $\alpha$ grains in both tested alloys.

3. Increase of strain rate during hot deformation of thermomechanically processed two-phase titanium
alloys causes rising of maximum flow stress $\sigma_{pm}$ and
decreasing of relative elongation $A$ at both 1123K and
1198K deformation temperature and strain rate range
applied – independently on their microstructure.

4. Essential effect of degree of initial deformation in
thermomechanical process is visible especially for the
lowest strain rate $\varepsilon = 1 \cdot 10^{-2}$ s$^{-1}$ and lower tensile test
temperature 1123K. Considerable rise of elongation $A$
was observed in alloys with finer microstructure – after
thermomechanical processing with higher degree of
initial deformation.

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titanium alloys containing Al, Mo, V and Cr. Rzeszow Univ.
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The Effect of Microstructure on Hot Plasticity of $\alpha + \beta$ Titanium Alloys

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Rzeszow University of Technology
DEPARTMENT OF MATERIALS SCIENCE

R&D LABORATORY FOR AEROSPACE MATERIALS
Achievement of desired mechanical properties is related to development of proper microstructure in plastic working and heat treatment processes.

During hot working of titanium alloys several factors make difficult or even preclude obtaining products having adequate microstructure and properties i.e.: high chemical affinity to oxygen, low thermal conductivity and high heat capacity and significant dependence of plastic flow resistance on strain rate.

Differences in temperature across the material volume, which result from various deformation conditions (local strain and strain rate) and physical properties of titanium lead to formation of zones having various phase composition (equilibrium α and β phases, martensitic phases α' (α")), morphology (equiaxial, lamellar, bi-modal) and dispersion (fine- or coarse-grained) and therefore various mechanical properties.
Fig. 1. The microstructure of Ti-6Al-4V alloy after die forging at 1223K
(Kubiak K.: Technological Plasticity of Hot Deformed Two-Phase Titanium Alloys)
THERMOMECHANICAL PROCESSING OF Ti-6Al-4V ALLOY

PHT  PD

PHT  PD  FHT

PHT  PD  FHT

SOLUTION HEAT TREATMENT

PD
Plastic Deformation
HOT FORGING

FHT
Final Heat Treatment

RECRYSTALLIZATION
THERMOMECHANICAL PROCESSING OF Ti-6Al-4V ALLOY

Microstructure

Solution heat treatment temperature

Without

β range

α+β range

Duration of crystallization

0h

0,5h

1h
Table 1. Chemical composition of selected $\alpha+\beta$ titanium alloys

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Al</th>
<th>V</th>
<th>Mo</th>
<th>Cr</th>
<th>Fe</th>
<th>Si</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti-6Al-4V</td>
<td>6.78</td>
<td>4.38</td>
<td>-</td>
<td>-</td>
<td>0.18</td>
<td>0.33</td>
<td>bal.</td>
</tr>
<tr>
<td>Ti-6Al-2Mo-2Cr</td>
<td>6.87</td>
<td>-</td>
<td>3.16</td>
<td>1.57</td>
<td>0.45</td>
<td>0.65</td>
<td>bal.</td>
</tr>
</tbody>
</table>
Table 2. Critical temperatures of $\alpha+\beta\leftrightarrow\beta$ phase transformation of as received titanium alloys

<table>
<thead>
<tr>
<th>Critical temperatures of $\alpha+\beta\leftrightarrow\beta$ phase transformation, K</th>
<th>Alloy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ti-6Al-4V</td>
</tr>
<tr>
<td>Start of $\alpha+\beta\leftrightarrow\beta$</td>
<td>1167</td>
</tr>
<tr>
<td>End of $\alpha+\beta\leftrightarrow\beta$</td>
<td>1252</td>
</tr>
<tr>
<td>Start of $\beta\leftrightarrow\alpha+\beta$</td>
<td>1215</td>
</tr>
<tr>
<td>End of $\beta\leftrightarrow\alpha+\beta$</td>
<td>1150</td>
</tr>
</tbody>
</table>
THERMOMECHANICAL PROCESSING OF Ti-6Al-4V AND Ti-6Al-2Mo-2Cr TITANIUM ALLOYS

Fig. 2. Open die forging
(forging reduction of about 50%)
MICROSTRUCTURE OF AS-RECEIVED Ti-6Al-4V AND Ti-6Al-2Mo-2Cr TITANIUM ALLOYS

Ti-6Al-4V

10 μm

Ti-6Al-2Mo-2Cr

25 μm
MICROSTRUCTURE OF SOLUTIONED Ti-6Al-4V AND Ti-6Al-2Mo-2Cr TITANIUM ALLOYS
MICROSTRUCTURE OF SOLUTIONED AND HOT DEFORMED Ti-6Al-4V AND Ti-6Al-2Mo-2Cr TITANIUM ALLOYS

Ti-6Al-4V

Ti-6Al-2Mo-2Cr

TMP-I

TMP-II
QUANTITATIVE METALLOGRAPHY

Methodology
### Table 3. Stereological parameters of microstructure of as-received and thermomechanically processed Ti-6Al-4V and Ti-6Al-2Mo-2Cr alloys

<table>
<thead>
<tr>
<th>Condition of Ti-6Al-4V alloy</th>
<th>$V_\alpha$ [%]</th>
<th>$a_\alpha$ [μm]</th>
<th>$b_\alpha$ [μm]</th>
<th>$f_\alpha$</th>
<th>Condition of Ti-6Al-2Mo-2Cr alloy</th>
<th>$V_\alpha$ [%]</th>
<th>$a_{\beta\text{prim}}$ [μm]</th>
<th>$b_{\beta\text{prim}}$ [μm]</th>
<th>$f_{\beta\text{prim}}$ [μm]</th>
<th>$R$</th>
<th>$G$</th>
</tr>
</thead>
<tbody>
<tr>
<td>As-received</td>
<td>82</td>
<td>4.1</td>
<td>5.3</td>
<td>0.77</td>
<td>As-received</td>
<td>76</td>
<td>137</td>
<td>42</td>
<td>3.26</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>TMP-I processed</td>
<td>59</td>
<td>51.3</td>
<td>3.2</td>
<td>16</td>
<td>TMP-I processed</td>
<td>34</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>TMP-II processed</td>
<td>79</td>
<td>23.2</td>
<td>1.1</td>
<td>21.1</td>
<td>TMP-II processed</td>
<td>40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>

Where:
- $V_\alpha$: Volume fraction of phase $\alpha$.
- $a_\alpha$, $b_\alpha$: Average linear sizes of phase $\alpha$.
- $f_\alpha$: Fraction of phase $\alpha$.
- $a_{\beta\text{prim}}$, $b_{\beta\text{prim}}$, $f_{\beta\text{prim}}$: Corresponding parameters for phase $\beta\text{prim}$.
- $R$, $G$: Additional parameters.
Fig. 3. Microstructure (TEM) of Ti-6Al-4V alloy after TMP-I process: fragmentation of α phase (a), globular secondary α phase grain (b); and after TMP II process: high dislocation density in α grains (c,d)
Fig. 4. Microstructure (TEM) of Ti-6Al-2Mo-2Cr alloy after TMP-I process: dislocation networks in $\alpha$ grains (a), lamellae of secondary $\alpha$ phase in the $\beta$ transformed matrix (b); and after TMP-II process: dislocations in $\alpha$ grains (c), subgrains in $\alpha$ phase (d)
HOT DEFORMATION

Conditions

Vacuum - $p = 0.005$ Pa.

Test temperature - 1123K and 1198K - below and within the range of $\alpha + \beta \leftrightarrow \beta$ phase transformation, respectively.

Strain rates - $1 \cdot 10^{-2}$, $1 \cdot 10^{-1}$ and $5 \cdot 10^{-1}$ s$^{-1}$.

Round specimens - diameter of 6 mm and gauge length of 8 mm (a).

The maximum flow stress $\sigma_{pm}$ and relative elongation $A$ were determined in tensile tests.
HOT DEFORMATION

Flow stress

Ti-6Al-4V

Ti-6Al-2Mo-2Cr

HOT DEFORMATION

Elongation

Ti-6Al-4V


Ti-6Al-2Mo-2Cr
CONCLUSIONS

1. Proposed thermomechanical processing causes transformation of microstructure of Ti-6Al-4V and Ti-6Al-2Mo-2Cr alloys from globular and lamellar respectively to highly deformed containing distorted and elongated α grains.

2. Increase of degree of initial deformation (forging) leads to formation of more elongated and refined α grains in both tested alloys.

3. Increase of strain rate during hot deformation of thermomechanically processed two-phase titanium alloys causes rising of maximum flow stress $\sigma_{pm}$ and decreasing of relative elongation $A$ at both 1123K and 1198K deformation temperature and strain rate range applied – independently on their microstructure.

4. Essential effect of degree of initial deformation in thermomechanical process is visible especially for the lowest strain rate (1·10^{-2} s^{-1}) and lower tensile test temperature 1123K. Considerable rise of elongation $A$ was observed in alloys with finer microstructure – after thermomechanical processing with higher degree of initial deformation.