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STABILIZATION OF THE TITANIUM VIBRATION DAMPING WIRES IN THE STEAM TURBINE BLADES SYSTEM

ABSTRACT

Damping wires are usually used for damping of vibration blades in the steam turbines. Chromium steels or titanium alloys are still applied materials for producing the vibration damping wires. In this paper the stabilization method of the titanium vibration damping wires in the steam turbine blades system is performed. Microstructure and mechanical properties of the damping wires made of WT3-1 titanium alloy after cold and hot bending processes were presented. Analysis of the investigation results cold and hot bended vibration damping wires suggest, that stabilizing by hot bending of the titanium wires in the steam turbine blades system can be used in practice with successful.

Key words: *steam turbines, titanium vibration damping wires, hot bending, mechanical properties*

INTRODUCTION

Typical turbine problems include pitting corrosion, corrosion fatigue, stress corrosion cracking, deposit buildup, solid particle erosion, water droplet erosion of the wet stages as well as fatigue failure of the vibration damping wires made of chromium steels [1-5]. The last years seen an increasing tendency to application the titanium alloys instead steels for producing the vibration damping wires used to damping of blades system vibration in low pressure stages of the steam turbines. Application of the titanium wires in low pressure stages demanded working out of a stabilizing technology in damping of blades system vibration, i. e. 200 MW steam turbines [6]. Elaboration of the optimal stabilizing technology of the titanium vibration damping wires in low pressure blades system of 200 MW steam turbine is a main aim of the present paper.

EXPERIMENTAL PROCEDURE

The material selected for producing the vibration damping wires was the titanium alloy WT3-1 (Ti6Al3Mo2Cr) from Russia, with the chemical composition and mechanical properties are given in Table 1.

***Table 1**. Chemical composition of the WT3-1 alloy*

Chemical composition, [% wt.]									Mechanical properties in 200ºC (Annealed state)			
Al	Mo	Cr	Fe	C	O	N	H	Si	Rm [MPa]	$R_{0.2}$ [MPa]	A_{10} [%]	Microstructure
5.5	2.0	2.0	1.0	0.1	0.2	0.05	0.015	0.4	910	740	11	α + β

Heretofore in practice, stabilization of the steels vibration damping wires was realized by cold bending of angle 14º10' (Fig. 1).

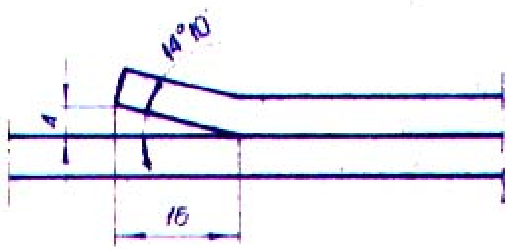

Fig. 1. The bended tip of the vibration damping wires

In present work the angle bend test of the samples vibration damping wires made of titanium alloy (WT3-1) was carried out by cold and hot bending method. The cold and hot bending (temperature 750-800ºC) processes of the tips of vibration damping wires were performed to moment, when first cracks have been observed. After hot bending test samples were air-cooled. View of the cold and hot bended tips of the vibration damping wires are shown in Fig. 2.

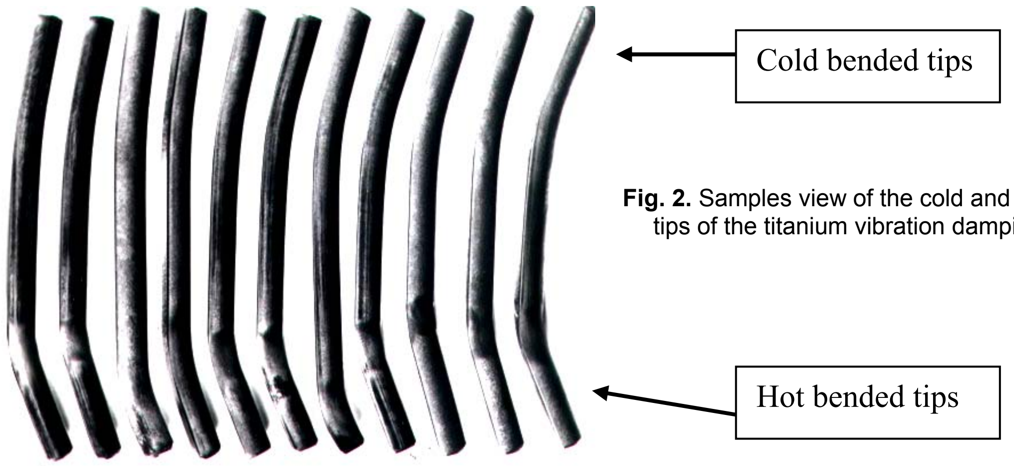

Fig. 2. Samples view of the cold and hot bended tips of the titanium vibration damping wires

Influence of the hot bending temperature process (750-800ºC) on the microstructure, hardness and tensile strength of the WT3-1 titanium alloy was analyzed. The microstructure was observed by the light microscope (LM) LAICA MEF4A/M, the surface hardness HV30 measured with Vickers-Brinell HPO-250 equipment and the tensile test was performed using Instron testing machine according to PN-EN 10002-1:1994.

RESULTS AND DISCUSSION

Table 2 shows the cold and hot bending test results of the samples vibration damping wires that the tips were bended to moment, when first cracks have been observed. The hot bending in temperature 750-800ºC of the tips of vibration damping wires enabled bend of them to angle average 34.6º compare to cold bended tips - 25.0º (Table 2). It means that hot bending in mentioned temperature make easy, without cracks the bend process of the vibration damping wires.

Table 2. *The bend angle to first cracks appearance of the samples vibration damping wires made of WT3-1 alloy*

Type of bending test of WT3-1 alloy	Bend angle to first cracks appearance, α [º]	
	From tests	Average
Cold bending	27	25.0
	25	
	27	
	24	
	22	
Hot bending in temperature 750-800ºC. Sample tips were heated for 12 s using the oxy-acetylene blowpipe.	38	34.6
	38	
	26	
	35	
	36	

Figure 3 presents the base microstructure of an annealed WT3-1 alloy and view of the cracks on the surface formed during the cold bending processes of the vibration damping wires. Microstructure of an annealed WT3-1 alloy was characterized by the coarse-grained, alternate lamellar α and β phases within the area of large grains of primary β phase (Fig. 3a). Heating at temperature 750-800ºC in the bending process, leads to changes of the vibration damping wires microstructure (Fig. 4). The lamellar microstructure of an annealed WT3-1 alloy (Fig. 3a) changed after heating to globular form of α phase in β phase matrix (Fig. 4a). The lamellar and globular mixed microstructure in the heat affected zone (HAZ) of the hot bended vibration damping wires were observed (Fig. 4b).

The globular microstructure ensures better strength, plastic properties and fatigue strength, while the lamellar microstructure only ensures better fracture toughness [7]. Titanium alloys with globular microstructure characterized more susceptibility to forming under hot working conditions [8, 9].

Influence the cold and hot bending processes on the hardness of the vibration damping wires is significant in the case of hot bending process (Table 3). Hardness test showed an increase of average hardness from 362HV30 in base material, to 385HV30 in hot bended zone. Probably this fact can be attributed to microstructure transformation (Fig. 4a) and small residual stresses residual after hot bending process.

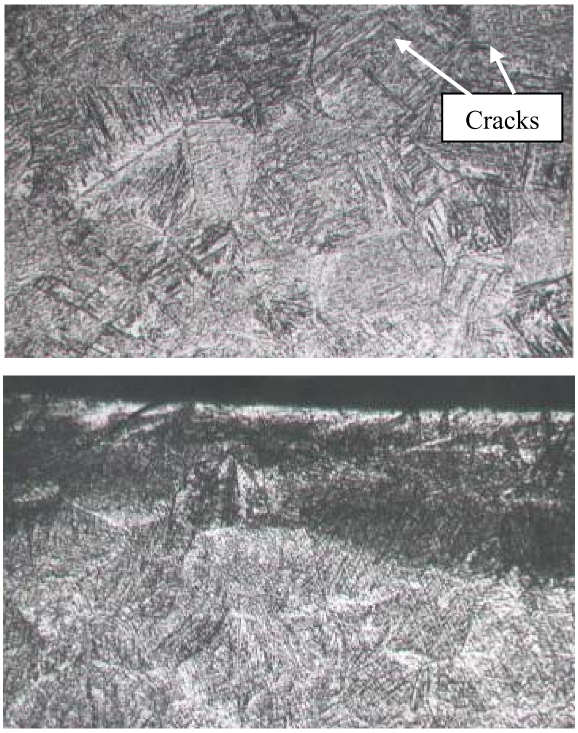

Fig. 3. Microstructure (LM) of the vibration damping wires made of WT3-1 alloy: a – base (annealed) material: (α + β) phases, b – cracks propagation on the surface of the cold bended wire

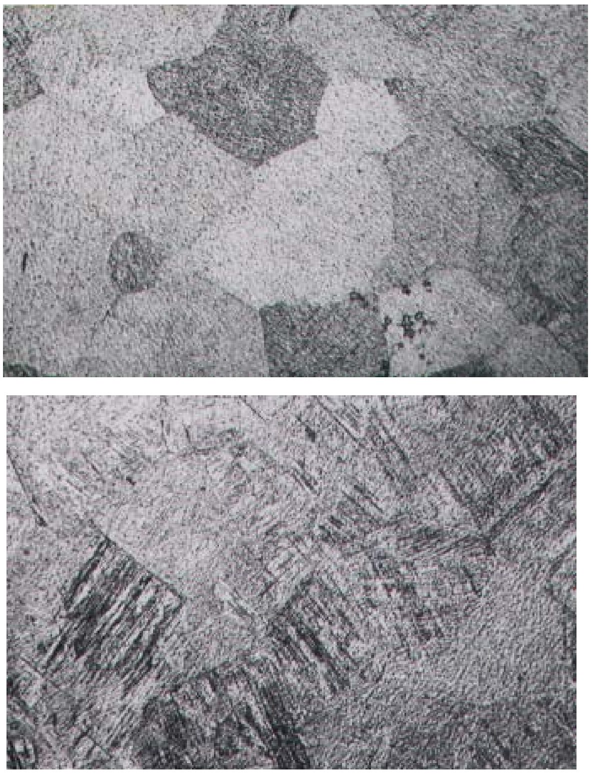

Fig. 4. Microstructure (LM) of the hot bended tips vibration damping wires made of WT3-1 alloy: a – (α + β) phases in heated area, b – HAZ between heated and base material

***Table 3.** Hardness of the cold and hot bended of the vibration damping wires made of WT3-1 alloy*

Type of bending test of WT3-1 alloy	Hardness HV30	
	Base material	Bended area
Cold bending	362	369
Hot bending in temperature 750-800ºC. (Sample tips were heated for 12 s using the oxy-acetylene blowpipe and slow cooled after bending).	363	385

Mechanical properties obtained from tensile test at temperature 150ºC for base material (annealed) and heated WT3-1 alloy at temperature 750-800ºC for 12 s using the oxy-acetylene blowpipe and then slow cooled are shown in Table 4.

***Table 4.** Mechanical properties of the WT3-1 alloy at temperature 150ºC*

Samples	Yield Strength [MPa]	Tensile Strength [MPa]	Elongation [%]	Reduction in Area [%]	Place of rapture
Base material (annealed)	918	977	16	48	In base material
Heated at temperature 750-800ºC for 12 s using the oxy-acetylene blowpipe and then slow cooled.	917	978	11	42	In heated zone

As demonstrated in Table 4, tensile and yield strength of the WT3-1 alloy in annealed also heated and slow quenched states are almost the same. However, the values of elongation and reduction in area of heated at (750-800)ºC and slow quenched the vibration damping wires are lost, 30.4% and 13.2%, respectively. That effect is observed due to transformation the lamellar microstructure at initial state (Fig. 3a), on the dispersion microstructure (Fig. 4a) in heat treated zone of the WT3-1 alloy.

CONCLUSIONS

1. Heating at (750-800)ºC for 12s with the aid of oxy-acetylene blowpipe and then slow quenching has not changed the tensile and yield strength, but simultaneously caused increase of the hardness and decrease of ductility of the vibration damping wires made of WT3-1 alloy.
2. Microstructure observations demonstrated that hot bending to angle of 34º no caused cracks on the surface of the vibration damping wires, while the cold bended wires near 18º were cracked.
3. Analysis of the mechanical properties and microstructure observations of the cold and hot bended wires showed, that hot bending for stabilization of the vibration damping wires in steam turbine blades system can be utilized.

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