International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-8 Issue-8S3, June 2019

Determination of Anisotropy Value by Compliance Parameter for Titanium Alloy OT4-1

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Abstract: The characteristic of a semi-finished product from a sheet of titanium alloy OT4-1 is the presence of anisotropy of mechanical properties along and across the direction of rolling (along and across the fibers). The purpose of the experiments was to establish magnitude of the anisotropy on the parameter of the compliance of the samples in these directions and to develop measures to reduce it. The tests were comparative in nature; circles with a diameter of 80 mm and a thickness of 0.5 ... 1 mm served as samples.

Keywords: Titanium, Technology, Stiffness.

I. INTRODUCTION

The accuracy of these holes has a great impact on the accuracy of the parameters of the holes and other elements produced in titanium sheets. Fundamentally, there are a number of ways for producing such holes, known as perforation. The methods include punching, drilling (countersinking, deployment), EDM processing, laser processing, and water jet cutting. These methods differ in their technical and economic indicators: processing accuracy, productivity, processing quality (roughness, the presence of a modified surface layer, regulated or unregulated residual stresses, etc.). An important point is the possibility of obtaining the sufficient accuracy of the relative position of the holes, largely determined by the process equipment used, as well as in the presence of a power factor during processing, by the rigidity of the technological system. The choice of the perforation method is also influenced by the part's material (the possibility of its processing in one way or another, considering the physicomechanical characteristics). The accuracy requirements listed above cause certain difficulties in achieving them. In particular, despite its high performance, the punching of holes is of little use for this part due to considerable forces (the bridges between the holes may break) and the difficulty of achieving accuracy requirements in diameter. Other listed methods can be fundamentally suitable for solving the problem; however, they require clarification and specification. With regard to this part (its low rigidity), it is important to keep in mind the state of the semi-finished product (sheet) including the presence of initial residual stresses and the possible anisotropy of mechanical properties associated with the characteristics of the car.

II. METHODS

The studied objects are circles from titanium alloy OT4-1 with a thickness of 0.5 and 1 mm. In the future, these blanks are supposed to produce small diameter holes with highly tolerable diameter and hole arrangement.

The measurement of compliance is shown in Fig. 1. A general view of the installation is presented in Fig. 2.

To eliminate the influence of force from a measuring device, for example, a dial-type indicator, the deflection was recorded by the difference in caliper between the initial and final positions of the head of the ELFA 731 electroerosion hardening installation with an accuracy of 0.01 mm whencontacting with the electrode -5. The cargo mass -7 in all cases was 0.2 kg.

The measurement process occurred in the following sequence:

1. Installation of the part -1 with the orientation of the fibers in one of the directions on the support -2 with a touch against the stop - 6 and clamp with a clamp - 4 by means of a screw - 3;

2. Measurement of deflection without load and determination of the initial position of the part in the vertical plane occurred in the following sequence:

3. Load application;

4. Measurement of the deflection of the part under load;

5. Unloading parts;

6. Unfastening the part and turning it 90 degrees in the horizontal plane to change the direction of the fibers (bending the part across the direction of the fibers);

Repeating procedures 1 - 5;

Revised Manuscript Received on May 23, 2019.

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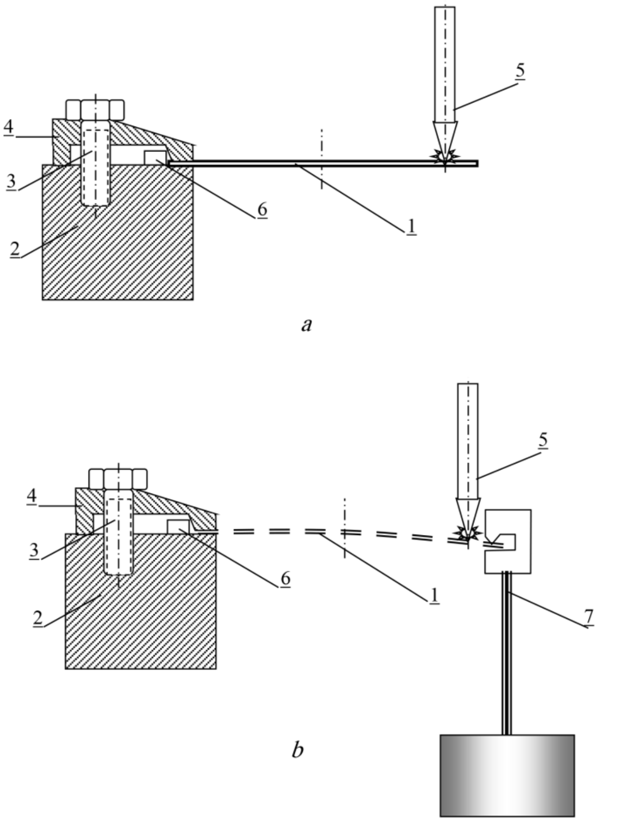

Figure 1. Scheme of measuring the stiffness of a round sheet
a- initial state, b- under load
1 — sample, 2 — support, 3 — screw, 4 — clamp, 5 — installation electrode, 6 — emphasis, 7 — cargo.

Measurements were carried out three times for each position with their subsequent averaging.

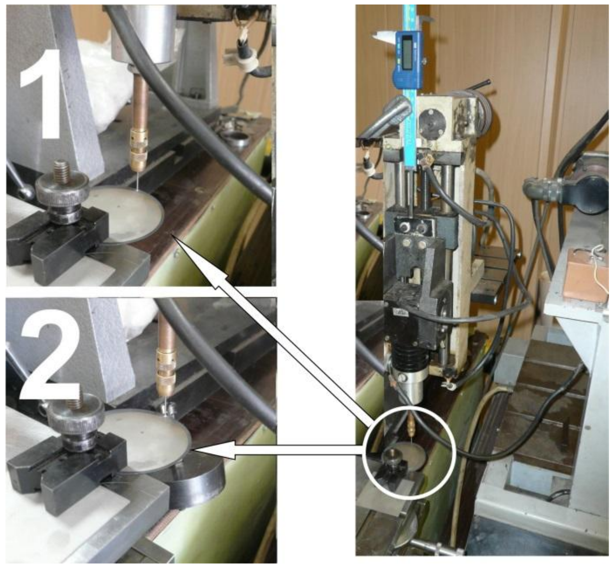

Figure 2. General view of the installation for measuring the deflection of sheet specimens.

1- Measurement of deflection without load, the definition of “0”; 2- Measurement of deflection of the part under the action of a load of 0.2 kg.

Heat treatment is used as a means of changing and eliminating the anisotropy of the mechanical properties of the material after metal forming. The following mode is recommended in the technical literature for alloy OT4-1: heating to a temperature of t = 640 ... 690 °C with an exposure for several hours. To broaden the understanding of the effect of heat treatment conditions, experiments were performed at temperatures of 850 and 900 °C. To eliminate the effect of gas saturation on the state of the surface layer of parts, heat treatment was performed in vacuum at a residual pressure of 10–2 ... 10–3 mm Hg.

The anisotropy of the mechanical properties of samples A and the change in their stiffness j were calculated according to the measurement results of the deflections along the y_b and across the y_n fibers:

$$A = \left|1 - y_n / y_в\right|,$$

$$j_{TO} - j_{ucx} = \frac{1}{y_{TO}} - \frac{1}{y_{ucx}}.$$

The results of the experiment are presented in Table.1.

Table 1. The deflection of parts in mm, along y_b and across y_p direction of rolling under the action of a load of 0.2 kg, the anisotropy of the mechanical properties A and the rigidity of the samples j

No.	TO	$y_в$	y_n	$y_в$	y_n	Anisotropy of mechanical properties A,%		Reduction in anisotropy, %	Stiffness change $j_{TO} - j_{ucx}$, %
		Original		After TO		in the initial state	after TO		
1	TO1	2.7	3.14	2.55	2.62	16.3%	2.7%	13.55%	
2		2.85	3.07	2.38	2.7	7.7%	13.4%	-5.73%	
3		2.85	3,.29	2.23	2.62	15.4%	17.5%	-2.05%	
Average value		**2.80**	**3.17**	**2.39**	**2.65**	**13.1%**	**10.9%**	**2.20%**	**2.70%**

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4	TO2	2.43	2.94	2.26	2.65	21.0%	17.3%	3.73%	
5		2.4	2.6	2.28	2.6	8.3%	14.0%	-5.70%	
6		2.35	2.66	2.31	2.6	13.2%	12.6%	0.64%	
Average value		**2.39**	**2.73**	**2.28**	**2.62**	**14.2%**	**14.6%**	**-0.39%**	**3.87%**
7	TO3	2.5	2.85	2.4	2.62	14.0%	9.2%	4.83%	
8		2.38	2.56	2.25	2.46	7.6%	9.3%	-1.77%	
9		2.45	2.61	2.3	2.45	6.5%	6.5%	0.01%	
Average value		**2.44**	**2.67**	**2.32**	**2.51**	**9.4%**	**8.3%**	**1.07%**	**4.36%**
TO1 *t*=720°C, excerpt τ=2h., TO2 *t*=850°C, excerpt τ=2h., TO3 *t*=900°C, excerpt τ=2h.									

According to the results of the experiment, it can be stated that with all the heat treatment modes, it was not possible to completely eliminate the anisotropy of the mechanical properties. The greatest decrease in anisotropy is observed after TO1, compared to other heat treatment modes (by average values). Intermediate values do not allow such an unambiguous conclusion. Their noticeable difference from the average values is probably due to the influence of the annealing conditions. For such an effect, we can consider the unequal location of the samples in the furnace. During heat treatment, the samples were placed in a package of three pieces. Samples No. 2, 5, and 8 were located in the middle of the package and to a lesser extent subjected to interaction with residual oxygen.

This is confirmed by the data on the change in stiffness, which increases with increasing temperature in the furnace (see Table 1).

Considering the purpose of the parts, it can be assumed that more rigid sheets are preferable to this node, since this may reduce the likelihood of electrode deflections during the operation of the optical system.

III. RESULTS AND DISCUSSION

According to the results of the experiment, it can be stated that with all the heat treatment modes, it was not possible to completely eliminate the anisotropy of the mechanical properties. The greatest decrease in anisotropy is observed after TO1 compared to other heat treatment modes (by average values). Intermediate values do not allow such an unambiguous conclusion. Their noticeable difference from the average values is probably due to the influence of the annealing conditions. For such an effect, we can consider the unequal location of the samples in the furnace. During heat treatment, the samples were placed in a package of three pieces. Samples No. 2, 5, and 8 were located in the middle of the package and to a lesser extent subjected to interaction with residual oxygen. This is confirmed by the data on the change in stiffness, which increases with increasing temperature in the furnace (see Table 1).

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