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Research paper

Comparison of Technological Methods for Small Diameter Hole Perforation in Titanium Alloys

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Abstract

There is a huge number of methods for hole obtaining. In view of the fact that an increasing number of parts demand an increased accuracy and roughness in the obtained holes, especially concerning thin sheet parts, there is the need of research in this field. The main goal of the work is to establish the most optimal method for small-diameter hole obtaining in titanium alloys. The sheet of titanium alloy OT4-1 is studied with the thickness of 0.5 mm. At the same time, rigid tolerances are established both for the holes themselves and for their location. Drilling, laser treatment and electroerosion ("super drilling") were chosen as the drilling methods. Other methods were not considered due to the possibility of aperture rupture between holes and other profile distortions for the part and the holes. The most optimal modes of hole obtaining were selected. The productivity, the quality and the accuracy of the holes were evaluated. They studied in detail the technologies for the obtaining of holes with the purpose of processing mode setting. The main recommendations were presented for an optimal method selection concerning the obtaining of small diameter holes in thin-sheet titanium alloys.

Keywords: *Titanium, technology, drilling, laser, electroerosion, holes*

1. Introduction

The object of the study is the 1sheets of titanium alloy OT4-1, with the thickness of 0.5 and 1 mm. In the sheet it is necessary to obtain the holes with the diameter of 1.4 +/- 0.01 and 2 +/- 0.01 mm with the tolerance of +/- 0.01 mm by pitch. There is the bridge between the holes with the thickness of 0.3 mm.

There is a number of ways to obtain such holes, called perforation. These methods include punching, drilling (core drilling, deployment), electroerosion processing, laser processing and hydroabrasive cutting. The listed methods differ in their technical and economic indicators: processing accuracy, productivity, processing quality (roughness, the presence of an altered surface layer, regulated or unregulated residual stresses, etc.). An important point is the possibility of the required accuracy obtaining for the mutual arrangement of holes, which is largely determined by the operated technological equipment, and also by the rigidity of the technological system in the presence of the force factor during the processing. The choice of the perforating method is influenced by the material of the part [1] (the possibility of its processing in one way or another taking into account the physico-mechanical characteristics). The abovementioned accuracy requirements cause certain difficulties during their achievement. In particular, the punching of holes is of little use for this part, despite a high productivity, due to considerable forces (it is possible to break the bridges between the holes) and the difficulty of accuracy requirement achievement along a diameter. Other listed methods may be suitable to solve a task in principle, but require clarification and specification. In view of the studied sample low rigidity, it is important to keep in mind the state of a semi-finished product (a sheet): the presence of initial residual stresses, possible anisotropy of mechanical properties associated with the characteristics of rolled products [3].

2. Methods

Electro-erosion of the holes was performed on Anchem HSD6-II device.

A sheet of titanium alloy OT4-1 was used. The thickness of the sheet was 0.5 mm. A sheet of greater thickness was not taken from the considerations that hole distortions and profile deflections are not fixed on the sheets with larger thickness. A series of holes with the diameter of 1.95 mm was obtained.

The processing mode was the following one:

Current $I = 4A$;

Voltage U=100 V;

$\tau_{имп} = 4000$ мс, $\tau_{пауза} = 3000$ мс

The working medium is water;

Electrode - brass

Electrode rotation frequency $n = 1000\frac{об}{мин}$,

Capacity C = 1 μF

The results of the treatment are shown on Fig. 1.

The cross-section of the holes after electroerosion is shown on Fig. 2.

The holes were obtained by the drilling on the machine MAHO MH500W.

Machining mode for drilling:

The number of tool revolutions $n = 4000\frac{\text{об}}{\text{мин}}$.

Feed $S = 0{,}05\ \text{мм/об}$.

VK6M tool was used made of a hard alloy.

Cooling is an aqueous emulsion.

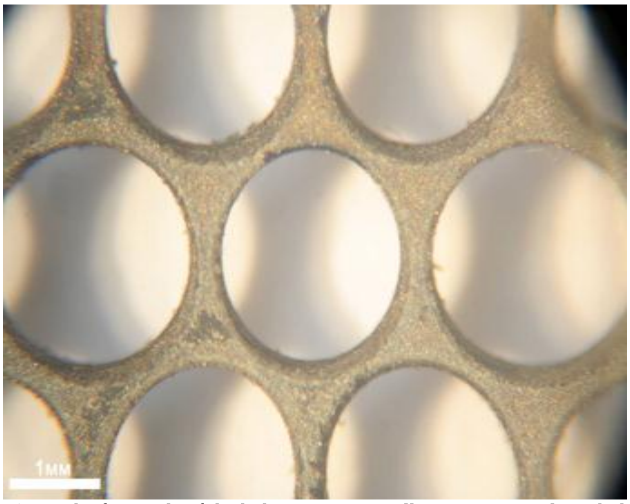

Fig 1: The front side of the holes on titanium alloy OT4-1 sample with the thickness of 0.5 mm obtained by the "super drill" method using Anchem HSD6-II unit.

The technology of hole drilling provided for:

Fig 2: The back side of samples from titanium alloy OT4-1 obtained by drilling on the CNC machine MANO 500 before the deburring and rinsing.

- The installation of a steel plate on the table and its fixing in the working area of the machine.
- The milling of the technological plate working surface as pure with the roughness Ra = 2.5 ... 5 µm.
- The installation of the workpiece on the process plate
- The fastening to the technological plate with clamps.
- The drilling of eight base holes with the diameter of 2 mm outside the part area.
- The installation of the pins in the base holes.
- The drilling of 1000 holes with the diameter of 1.4 mm according to the program (1500 holes with the diameter of 2 mm) according to the modes indicated above.
- Tool change regardless of its condition, wear control and sharpening.
- The removal of the technological sheet and the part from the machine.
- The part flushing.
- The part drying (the blowing with compressed air).
- The deburring with an abrasive paper.
- The control of workpiece dimensions and processing quality.
- The sample is shown on Figure 3 after drilling.
- The holes were obtained with a laser using the "Bystar 3015" unit.
- The rated power of the unit made 3 kW.

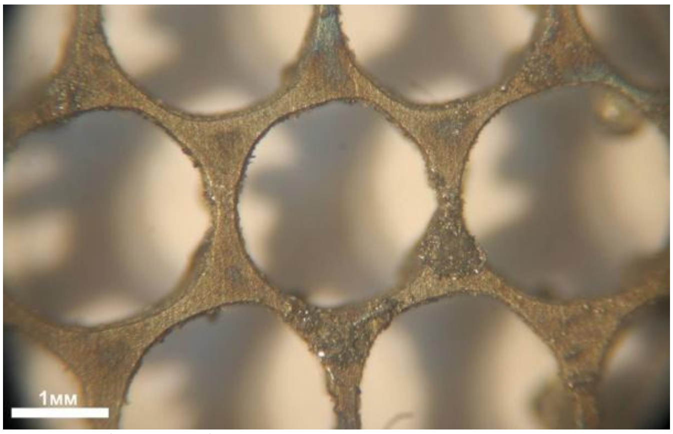

Fig 3: The front side of the holes on titanium alloy OT4-1 sample with the thickness of 0.5 mm obtained on a laser device "Bystar 3015". A continuous operation mode made 30% of rated power. The speed made 5000 mm/min, the gas pressure made 6 bar.

The sheet of titanium alloy OT4-1 was also used for electric erosive processing. The thickness of the sheet was 0.5 mm. A sheet of a greater thickness was not taken from the considerations that profile distortions and hole deflections were not fixed on the sheets with larger thickness. The series of holes with the diameter of 1.95 mm was obtained.

3. Results and Discussion

During a detailed examination of the obtained drawings (Fig. 1 and 2), it can be stated that the shape of the holes after the electric erosive processing is round. There is no cutting, ovality, etc. This is typical for entrance and exit side of the instrument. When you analyze the section of a hole, one can judge its taper.

After the treatment with electroerosion, a modified surface layer characteristic of this process can be noted on the hole surface. Surface roughness can be considered as an acceptable for this type of hole size.

In the experiments carried out, the task was not to obtain the hole diameter of 2-0.05 mm due to the obvious need for another dimensional processing aimed at taper correction and the part of the surface layer removal.

As was noted above, laser processing was performed on the laser unit "Bystar 3015". It should be noted that almost in all cases there is the lack of hole roundness after laser treatment, the formation of cuts and notches, and the conicity of a hole is visible after lazer processing. Splatters from the frozen metal are formed on the front side of the samples and burr is present on the output edge of the holes. In order to correct the abovementioned drawbacks, it is necessary to perform mechanical dimensional processing, which involves some difficulties due to the development of solid deposits both in the holes and next to them. Also, there is the burn of jumpers in some cases.

The holes were processed by drilling on a CNC machine MAHO MH500W. The drawbacks of this hole obtaining method include the development of minor burrs at a hole inlet and outlet. A hole shape is correct in all sections (no taper, ovality, etc.). The roughness is at the level of Ra = 1.25 µm. The changed surface layer is absent. The diameter of the holes corresponds to the requirements of the drawing.

Based on the measurement of time, you can calculate the productivity of all types of processing. For the electric erosive treatment "super drill" the productivity makes 0.8 rev/min. The drilling processing on a CNC machine makes 10 ... 15 holes/min.

The productivity of laser processing is presented in Table 1.

Table 1: Laser processing productivity.

Sample №	Number of holes	Hole diameter, mm	Processing time, s	Performance, holes/min.
w/n	48	1,95	58	49,7
3	52	1,8	85	36,7
2	52	1,8	80	39,0

It should be noted that it is necessary to change the drilling tool in time. The stability of a single drill in operation was chosen equal to 1500 holes, and then it was grinded. The number of grindings is 10 or more times. One can process one part with a large number of holes by a single drill (1500-3000 holes). A drill bit is selected for reasons of drill durability limitation, the geometric parameters of the tool cutting part, and based on the nature of chip development. It is important that the type and the size of chips allow to remove it effectively from the processing zone.

For the reasons outlined, it is recommended to choose the method of drilling holes with the subsequent deburring, rinsing and drying.

4. Summary

It can be concluded that, given the hardness and other physical and mechanical properties of titanium alloys, drilling is the most optimal method of hole obtaining in a thin titanium sheet. Drilling methods and laser processing require additional dimensional processing, which increases the total processing time. It should be noted that the dimensional processing of deployment type can be at least 20% of drilling time.

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