ISOSTATIC PRESSURE OF HIGH-STRENGTH TITANIUM ALLOYS

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ANNOTATION

Results of studies of the effect of hot isostatic pressure (HIP) on mechanical properties of VT22 and VT35 high strength titanium alloy castings are reported.

Key words: titanium alloys, hot isostatic pressure, mechanical properties.

1. INTRODUCTION

Shape casting is an advantageous procedure for manufacturing of parts from titanium alloys. It provides production of net-shaped intricate parts. Consumption of expensive metals and scope of labour-intensive machining can be reduced due to the above [1].

Formation of shrinkage porosity and cavities is one of the reasons limiting a broad application of this procedure. An increase in alloying degree leads to an increase of solidification temperature range causing the susceptibility to formation of interdendritic shrinkage porosity. This feature affects mechanical properties of castings.

The common procedure for elimination of cavities and porosity (welding up of defect areas) does not allow to improve significantly mechanical properties [1].

That is why titanium alloys usually used for shape castings have low or medium alloying degree. Strength of these alloys does not exceed 900-1000 MPa.

Development of shape casting of titanium alloys involves, first of all, hot isostatic pressure (HIP) into the technological cycle and provides possibility of application of high-strength wrought alloys for shape casting and an improvement in strength properties of castings [2]. It is especially efficient for an improvement of fatigue resistance highly depending on the structure [3].

2. MATERIALS AND EXPERIMENTAL PROCEDURE

The studies were conducted using castings from the following titanium alloys (% mass.); VT22 (5Al, 5Mo, 1Cr, 1Fe) and VT35 (3Al, 15V, 3Cr, 3Sn) [4].

Centrifugal casting was used for production of the following specimens:

- Φ12x80 mm cylinders - for VT35 alloy
- Φ12x80 mm cylinders and 300x200x20 mm plates - for VT22 alloy.

Hot isostatic pressure was executed in a HIP-unit at 820-910°C and 110-120 MPa.

The specimens were heat treated in electric air furnaces.

Mechanical properties (σ₀, σ₂, δ, ψ, σ₁ on the base of 1x10⁷ cycles) of castings were determined according to requirements of the GOST (Russia State Standards).

Metallographic investigations were conducted on NEOFOT optical microscope and scanning electron microscope MSM5.

3. EXPERIMENTAL RESULTS AND DISCUSSION

X-ray analysis of VT22 alloy castings in initial state showed that they have shrinkage-caused discontinuities up to 1-10 mm in size.

The castings showed a low level of plasticity and a wide spread in mechanical properties caused by the presence of internal discontinuities. Mechanical properties of specimens cut out from the castings wherein X-ray analysis did not reveal defects are given in Table 1.

According to the data of X-ray analysis, HIP at 110-120 MPa and 820-910°C, 1-2 hrs allowed to eliminate internal discontinuities.

As-hipped specimens were heat treated under conditions applied for wrought material (step-by-step annealing and double annealing). Results of mechanical testing of the said specimens are given in Table 1.
Table 1

Mechanical properties of VT22 alloy castings

<table>
<thead>
<tr>
<th>HIP conditions</th>
<th>Heat Treatment</th>
<th>Mechanical Properties</th>
<th>ψt, %</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>σb, MPa</td>
<td>δ, %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>820°C, 1 hr</td>
<td>1120 - 1130</td>
<td>6.8 - 8.8</td>
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<tr>
<td></td>
<td>double annealing</td>
<td>1140 - 1170</td>
<td>2.0 - 4.0</td>
</tr>
<tr>
<td></td>
<td>step-by-step annealing</td>
<td>1090 - 1120</td>
<td>4.8 - 5.6</td>
</tr>
<tr>
<td></td>
<td>910°C, 1 hr</td>
<td>1200 - 1280</td>
<td>2.0 - 4.8</td>
</tr>
<tr>
<td>820°C, 1 hrs</td>
<td>double annealing</td>
<td>1083 - 1095</td>
<td>4.4 - 12.0</td>
</tr>
<tr>
<td>910°C, 1 hrs</td>
<td>770°C, 2 hrs</td>
<td>1173 - 1180</td>
<td>2.2 - 3.3</td>
</tr>
<tr>
<td>840°C, 2 hrs</td>
<td>770°C, 2 hrs</td>
<td>1036 - 1061</td>
<td>11.2 - 14.4</td>
</tr>
<tr>
<td>840°C, 2 hrs</td>
<td>600°C, 8 hrs</td>
<td>1166 - 1188</td>
<td>6.4 - 8.0</td>
</tr>
</tbody>
</table>

Analysis of the obtained results and their comparison with mechanical properties of wrought metal showed the follows:
1. Ultimate strength of castings is near to that of the wrought material heat treated under the same conditions.
2. Plastic characteristics of castings (especially after heat treatment to obtain higher strength level) are lower than that of the wrought material.
3. Mechanical properties of casting having shrinkage - caused discontinuities after HIP and step - by - step annealing are practically the same as those of castings without HIP if there were no defects found by X - ray analysis.

The main factor affecting on mechanical properties is the cast structure (large - sized grains, unfavourable morphology of α particles). This structure does not practically change during HIP and heat treatment.

Since HIP can serve as the first step of annealing of VT22 alloy, mechanical properties of castings annealed at 770°C, 2 hrs and 600°C, 8 hrs were evaluated.

Heat treatment at 820°C, 1 hr and 840°C, 2 hrs was executed after HIP. Results of mechanical testing are given in Table 1.

The above results allow to state:
1. Plastic characteristics of castings are higher and more stable after HIP at 840°C, 2 hrs.
2. Properties of hipped castings after step - by - step annealing and after annealing carried out at the temperature of the second step only are practically the same.

Evaluation of fatigue resistance of castings after HIP and heat treatment under various conditions showed that fatigue resistance (σ; on the base 1x10⁷ cycles) is 400 - 500 MPa depending on their strength within 1050 - 1200 MPa range.

The studies conducted showed that the combination of mechanical properties of VT22 alloy castings after HIP and heat treatment is near to those of large - sized semiproducts manufactured from this alloy at the temperature of one - phase β field.

Susceptibility to shrinkage - caused microporosity of high - temperature VT35 alloy (β alloy) is higher than that of VT 22 alloy (Fig. 1).

Metallographic and X - ray studies showed that HIP at 850 - 900°C provides healing of internal discontinuities (cavities and pores) do not appearing on the surface.

Results of mechanical testing of VT35 alloy castings after HIP and heat treatment under various conditions (quenching from one - phase β field temperature, ageing of the quenched specimens and as - hipped specimens) allows to note the follows.

Specimens after HIP and strengthening heat treatment applied either just after HIP or after quenching showed high level of strength (1150 - 1500 MPa depending on ageing conditions).

A part of specimens had a good combination of strength and plastic properties both in quenched state (σb=890 MPa, σ0.2= 820 MPa, δ= 14%, ψ= 45%) and after strengthening heat treatment (σb=1150 - 1220 MPa, δ=5 - 7%, ψ= 11 - 14%).

At the same time there is an instability of mechanical properties (especially for plasticity) of the specimens in all studied states. Obviously, it is caused by coarsening of grains and their different size in the cast structure.
Fig. 1 Shrinkage - caused microporosity of VT35 alloy castings: a) - microstructure; b) - fracture surface after tensile tests.

4. CONCLUSIONS

The studies undertaken confirm the advantage of application of wrought high - strength titanium alloys in production of shaped castings. It is expedient to carry out additional investigations on modification of the said alloys and optimization of heat treatment conditions in order to improve the level and stability of plastic properties.

REFERENCES: