CAST EQUIPMENT FOR HEAT TREATMENT FURNACES

ЛИТЕЙНОЕ ОБОРУДОВАНИЕ ТЕРМИЧЕСКИХ ПЕЧЕЙ

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***Abstract**: Various designs of equipment used in heat treatment furnaces are presented. The equipment is assembled from components varying in shape and size. In this case study it is composed of castings only. Castings are made from creep-resistant alloys, mainly cast austenitic steel and nickel alloys, using gravity poured sand molds. The design should allow for the simultaneous solidification of all thin-walled cast parts. The study focuses on the equipment for the heat treatment of parts of uncommon shape and size, or parts that require special heat treatment conditions. It is used for the charge formation in furnace and transport of this charge inside and outside the furnace. Different designs are illustrated. Their shape and size depends on the type of furnace, production volume, and the number and shape of heat-treated parts.*

KEYWORDS: CASTINGS FOR HEAT TREATMENT PLANTS, TECHNOLOGICAL EQUIPMENT, GRATES, BASKETS

1. Introduction

A part of tooling in most heat treatment furnaces is the technological equipment used for the formation of charge and its transport inside and outside the furnace. The performance life of this equipment often determines the reliability and durability of the furnace [1–3]. There are three procedures commonly adopted in the design of this equipment, each of them depending on the type of furnace, production volume, and the number and shape of heat-treated products. Future user of the equipment must decide on the choice of one of the following solutions [3]:

1. Use standard furnace equipment provided by the manufacturer, and then, depending on current production needs, add to this equipment, within his own capacity, other complementary elements for handling of the heat treated parts.
2. Use in standard furnace the equipment of his own non-standard design.
3. Order at a manufacturer a nonstandard furnace and install in this furnace the pre-designed equipment of nonstandard shape and size.

This study describes a user-tailored type of technological equipment, designed for the heat treatment of selected parts of machinery in a furnace of uncommon design. The need to take a "special approach" to the design of the equipment was dictated by:

- the shape and size of heat-treated parts,
- the need to increase the durability of the equipment,
- specific heat treatment parameters,
- other requirements essential for the required quality of heat-treated parts and reduced cost of their production.

The presented equipment has been made from cast components only, using creep-resistant alloys, mainly cast austenitic chromium-nickel / nickel-chromium steel and nickel alloys [3–5].

2. Design of the equipment

In designing of the equipment, the engineer is guided by the following principles [1, 3, 6–9]:

1. As far as possible, both the equipment and the heat treated parts should form a compact whole.
2. The mate components of the equipment should be joined together in a loose way. Loose fit allows free heat distortion of connected components in the range of operating temperatures. It also makes the replacement of worn out parts much easier.
3. Different components of the equipment should have the same wall thickness and the walls should be as thin as possible. It is recommended to avoid heavy build up of material separated by thin walls from other components.

The equipment shown in Figures 1–10 has been designed in accordance with the requirements formulated earlier. The individual components are connected with pins.

The equipment for the heat treatment of shafts of a wind turbine (Fig. 1) is designed for use in a pit furnace. The heat-treated batch consists of three shafts, each weighing 920 kg (Fig. 1a). The weight of the equipment alone is 1280 kg and the whole is composed of 72 pieces (Fig. 1b).

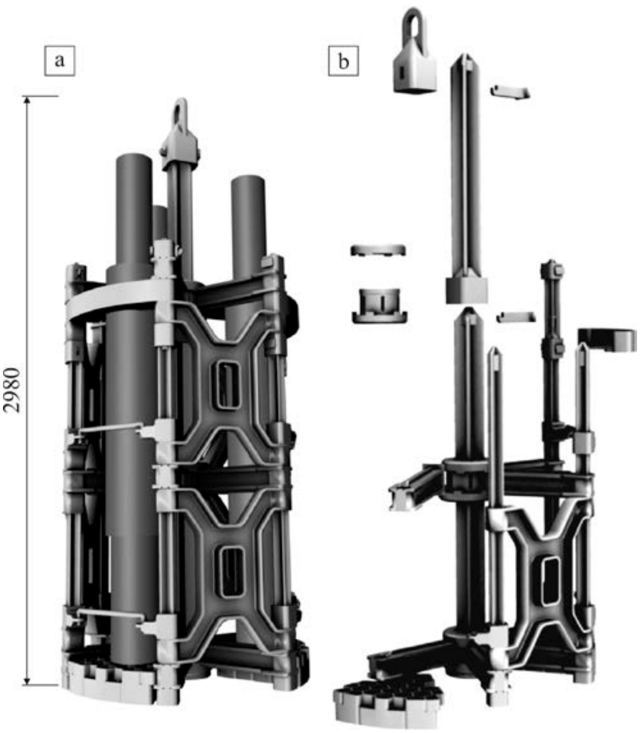

***Fig. 1.** The equipment for the heat treatment of shafts of a wind turbine: a) general view [3, 9], b) single components*

The equipment shown in Figure 2 is used for the heat treatment of turbojet engine gas guide vanes. The process of heat treatment is the last one in the refurbishment cycle of these vanes. The user request was to set the guide vanes in a vertical position in the equipment using base elements, for which the additional design was made (Fig. 2a). However, with this setting of the treated parts, any change in the equipment position during transport would have to be done with utmost care, since the gravity center of heat-treated parts would be located at a considerable height. Changing the setting of heat-treated parts (Fig. 2b) eliminated this inconvenience, bringing additionally a number of other advantages, to mention as an example the loading capacity of the equipment increased from 18 to 20 parts, the overall weight of the equipment reduced by 150 kg, and the manufacturing cost reduced by 12%. Then the total weight of the equipment (Fig. 2b) was 414 kg, and it consisted of 42 items, this including 29 pins.

The equipment for the heat treatment of turbojet engine rotor blades (Fig. 3) is a good example of how the conversion from a welded structure to a structure composed entirely of castings can increase the life of the elements [3, 10].

This equipment is to be used in a hood furnace. The weight of the modified structure (Fig. 3a) is 280 kg. The equipment is composed of 261 parts (Fig. 3b), of which 192 are hooks for hanging the individual heat-treated blades (Fig. 3a).

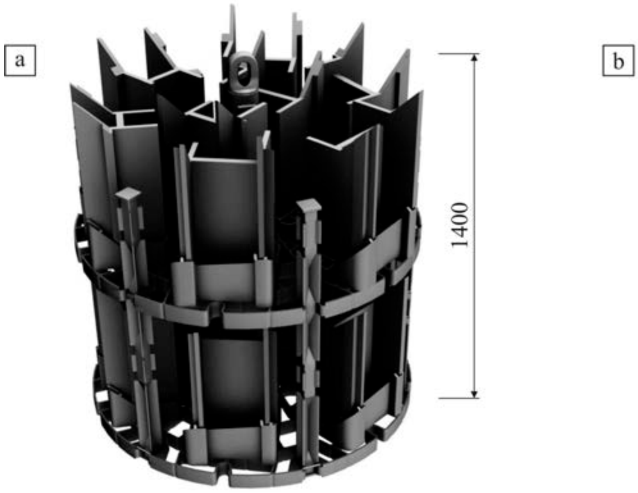

Fig. 2. *The equipment for the heat treatment of turbojet engine gas guide vanes [9]: a) initial design, b) modified design*

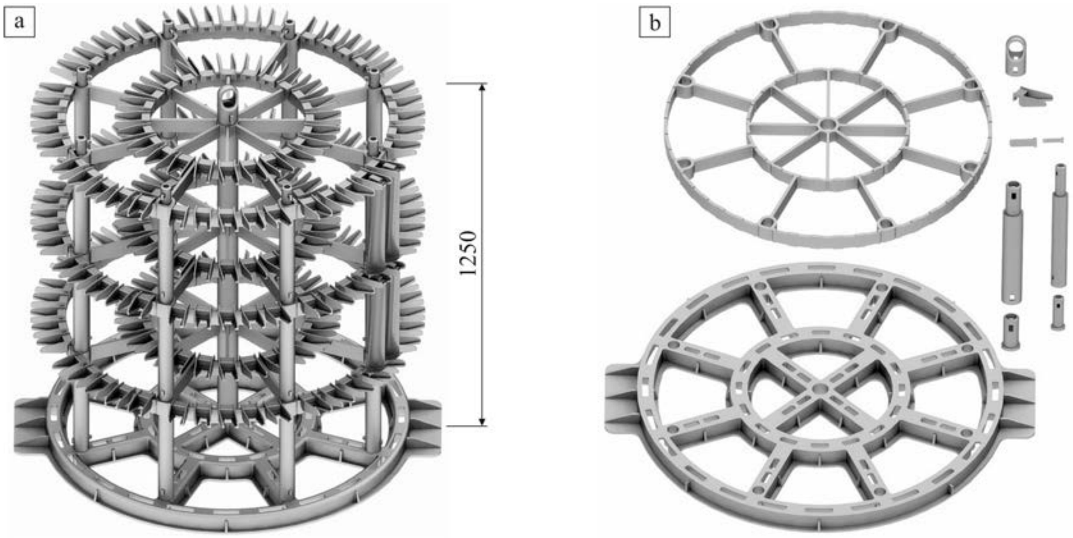

Fig. 3. *The equipment for the heat treatment of turbojet engine rotor blades [3, 9]: a) general view, b) single components*

In the next step of the modification of the equipment design (Fig. 3a), also the hook, on which the blades are hung, was modified (Fig. 4). This change significantly increased the number of blades heat treated in a single cycle.

Fig. 4. *Increased capacity of the equipment shown in Fig. 3a by the use of double hook [9]*

The equipment shown in Figure 5 was designed for the heat treatment of tension springs for railway electric traction. It was to be used in the pusher furnace. The design of the equipment shown in Figure 5 was tailored to the user specific needs; hooks were introduced to facilitate transport outside the furnace.

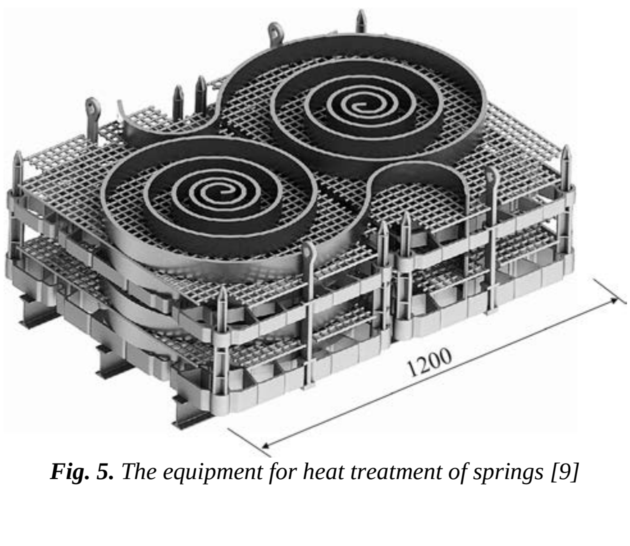

Fig. 5. *The equipment for heat treatment of springs [9]*

Baskets are commonly used in the heat treatment process, especially when the process of annealing is done on small parts. The use of baskets allows maximum utilization of the furnace working space and facilitates work organization. The equipment shown in Figures 6 and 8 has been designed with a view to encouraging the users of baskets welded from the wrought semi-products to switch over to the use of baskets made of cast components.

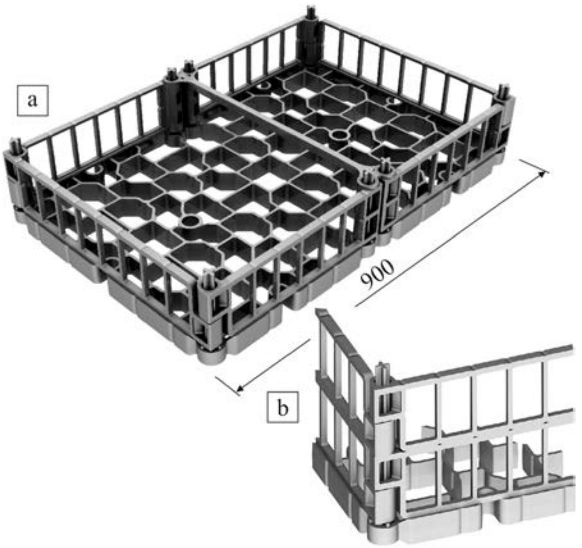

Fig. 6. *Basket: a) general view, b) high capacity design with additional side walls [9]*

Basket (Fig. 6a) is a sort of container designed for the heat treatment of small parts in the chamber furnace. Parts are placed in a basket in bulk. Long columns allow increasing the loading capacity of the basket, since a number of extra side walls can be added (Fig. 6b).

Welded baskets (Fig. 7) for annealing of the cast gearbox bodies are used in the roller pusher furnace. The one shown in the drawing has been replaced with a basket made of cast components (Fig. 8a). The basket has a weight of 440 kg and consists of 32 castings.

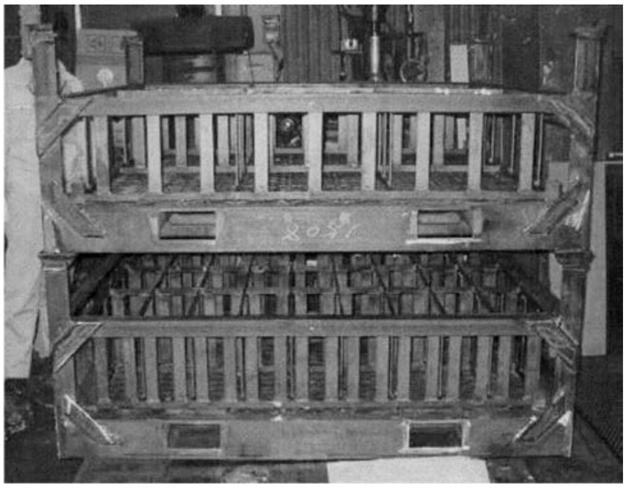

Fig. 7. *Welded basket for annealing of gearbox bodies [3, 10]; the gearbox bodies are placed in separate compartments of the basket*

Some fragments (or the entire surface) of the ceramic lining of the furnace for heat treatment may require shielding or other means of protection to prevent them from getting damaged during operation.

The equipment shown in Figure 9 illustrates the method of protecting the ceramic hearth of a bogie hearth furnace from mechanical damage during loading / unloading of charge.

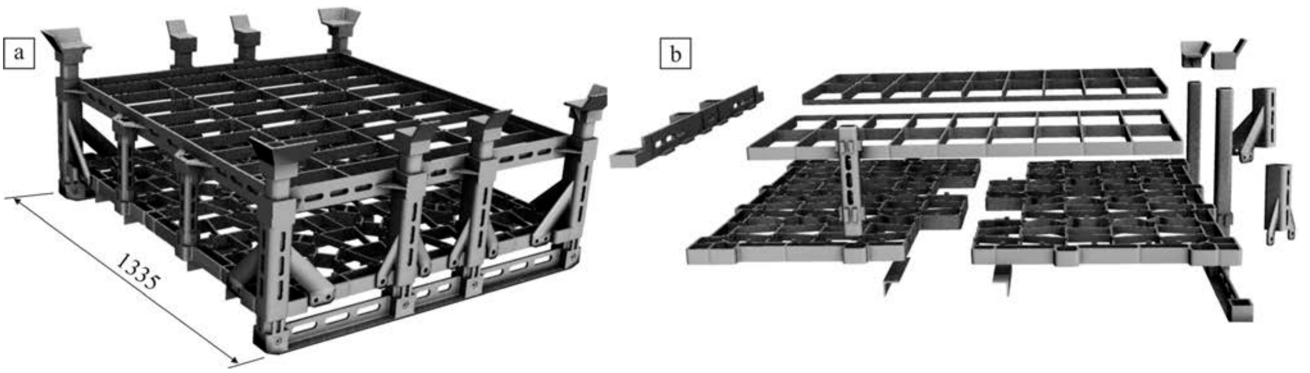

Fig. 8. *Modified design of basket shown in Figure 7 [3, 9]: a) general view, b) single components*

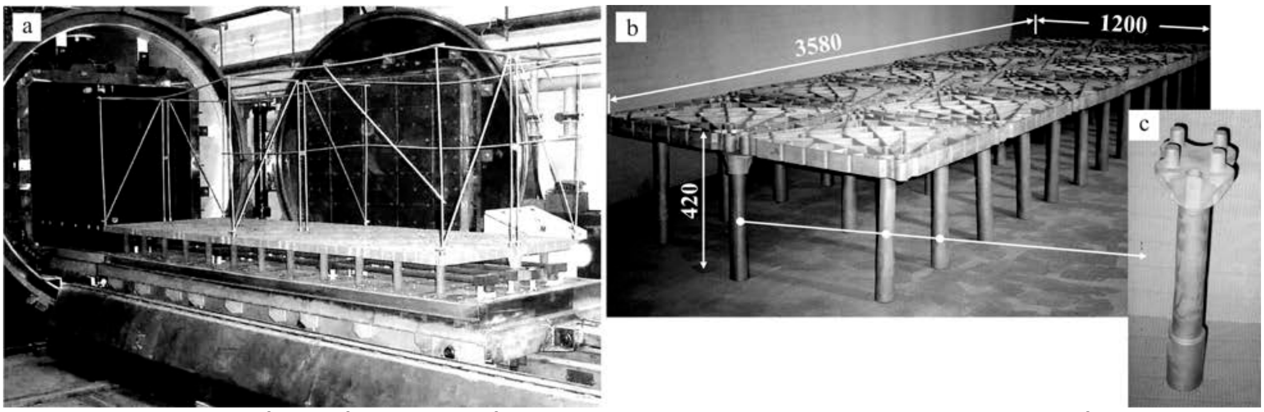

Fig. 9. *Vacuum bogie hearth furnace for annealing of metal powders [3, 9]: a) general view; construction welded from steel rods set on a stem indicates the space occupied by the containers in which the charge is placed, b) the core made from pallets and racks set on the furnace hearth*

The hearth of the furnace is provided with an electrical heating system arranged on a ceramic substrate (Fig. 9a). The equipment, in addition to protecting the hearth of the furnace, has also another task, namely that of maintaining a stable position of the heavy charge above the heaters without constituting a significant barrier to heat flow in this area. To ensure that these requirements are met, a base was designed that consists of 12 openwork pallets and 30 columns (Fig. 9b, c). The columns with heads ending in bolts (Fig. 9c) join palettes together. Loose connection of these elements enables them (and the equipment) to undergo free heat distortion in the range of operating temperatures.

In the process of hardening products made of titanium alloys it is necessary to cool them very rapidly in a cooling liquid. Additionally, the heat treatment process is difficult to carry out if products are heavy and intricate. The equipment for the heat treatment of parts made from titanium alloys is shown in Figure 10.

The equipment (Fig. 10) is designed for the heat treatment of parts of the aircraft chassis. It consists of 55 components with a total weight of 450 kg. The main components of the equipment are: a body with a transport hook, a latch (Fig. 10–1, 2) and a sling (Fig. 10–3). The charge of up to 2500 kg is hung on sling hooks (Fig. 10–4). The equipment with the charge is suspended under a crane and introduced into the furnace chamber. In the furnace it is held at a predetermined temperature for a predetermined lapse of time. Then, together with the furnace, it is placed above the liquid coolant reservoir and lowered into the reservoir under its own weight.

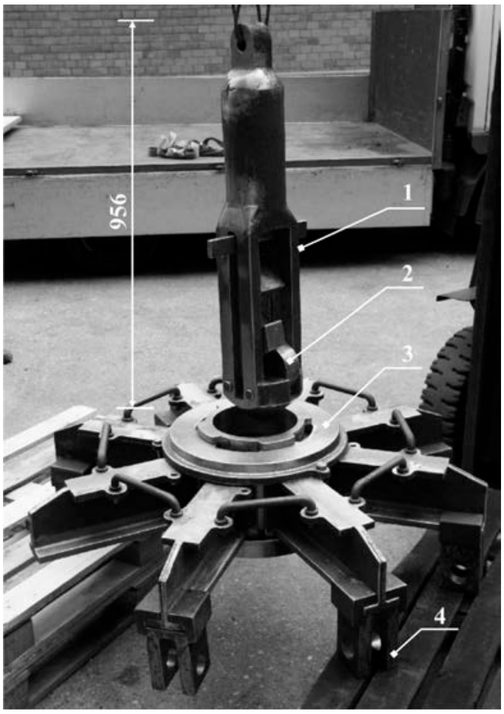

Fig. 10. *The equipment for the heat treatment of parts of the aircraft chassis [3]: 1 – body with transport hook, 2 – latch, 3 – sling, 4 – clip for fastening of heat treated parts*

3. Final remarks

When the described components of the technological equipment were designed, three groups of factors that determine the reliability and durability of this type of construction were examined [3]. These factors include:

1. Construction – operating conditions (temperature changing in a wide range of the operating values) and the expected parameters of the heat-treated charge (size, shape, weight).
2. Material – chemical and phase composition, as well as the morphology of microstructure providing the required creep properties during operation.
3. Casting – the use of technological solutions in the manufacture of castings, which guarantee low level or complete elimination of defects, both external and internal.

When decisions are made jointly by the manufacturer and foundry process engineer as to the selected material, design and technology, it should be remembered that the results of the operation of these three factors overlap and together affect the life and stability of the equipment considered as one integral whole.

All variants of the equipment shown in Figures 1–9 were designed by the authors of this study. Most of the types have already been used in industrial practice, in whole or in part. In the case of the equipment shown in Figure 10, the authors participated in the process of its manufacture. All designs are protected by intellectual property laws.

4. References

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