THEORETICAL AND EXPERIMENTAL CONSIDERATIONS REGARDING THE REALIZATION OF A HEAT TREATMENT FURNACE

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ABSTRACT: The structure of this article details the elements of design, execution and operation of a heat treatment furnace (TT). It features a gas-based cylinder heat source supercharged by a blower that brings extra air to the centrally arranged burner area in the upper furnace panel. The walls of the furnace enclosure are lined with refractory brick, the housing consists of steel sheet S235JR and is placed on 4 feet that allow to adjust the vertical position of the furnace by means of screw assemblies. The oven temperature is adjusted by means of onehour taps that offer the possibility of varying the flow rate of the fuel mixture and the additional air flow brought by the blower. The indoor temperature is monitored using a thermocouple. The furnace also features a metal door lined refractory. The performance of the furnace in operation can be assessed based on the temperature reached, the heating speed, the controlled cooling speed (in air flow, possibly), based on the types of TT that can be achieved on this furnace.

KEYWORDS: heat treatment furnace, fuel gas, manual welding,

1. Introduction

Heat treatments are widely used processes in industrial engineering and metalworking, used to alter the physical and mechanical properties of metal materials [1]. These treatments involve controlled heating and cooling of materials in specialized furnaces to obtain desired characteristics such as: hardness, ductility, machinability, wear resistance, corrosion resistance, etc. [2]. In addition, heat treatments can improve the performance of parts during operation and extend their service life [3].

The purpose of this heat treatment furnace is to allow the realization of heat treatments for relatively small parts in the research laboratory of the Department of Quality Engineering and Industrial Technologies (ICTI). The main objectives of the project include the development of an efficient and versatile furnace that can perform different types of heat treatments, such as annealing, normalization, quenching and tempering [4].

The furnace will be designed to achieve high temperatures and to allow precise control of the heating and cooling speed in order to ensure an even distribution of heat inside the furnace. Another important objective of the furnace is to be economical and environmentally friendly, using a gas-based heat source of a cylinder supercharged with additional air brought by a blower [5]. The furnace must also be easy to use and maintain so that it can be used effectively in the research laboratory.

2. Design of the heat treatment furnace

The designed heat treatment furnace will have the overall dimensions of 450 x 400 x 250 mm, being designed to fit into the workspace of the research laboratory of the ICTI department and to meet the heat treatment requirements of the relatively small parts. These dimensions were established following a rigorous analysis of functional requirements and space limitations.

The inside of the furnace will include a central area for heating parts, as well as spaces for the gas supply system, burner and auxiliary components.

The furnace housing and the access door were made of S235JR steel sheet, with a thickness of 4 mm. Steel S235JR is a material with physical, mechanical, technological and chemical properties suitable for the construction of the heat treatment furnace [6].

This type of steel has a moderate tensile strength, good ductility and excellent weldability, being suitable for use in metal construction applications in general [7].

The S235JR steel has a thermal conductivity of around 60 W/m·K, which means that it allows a good transfer of heat through conductivity and in what means the evacuation of heat through radiation it has a moderate thermal radiation. The flow limit of the S235JR steel is about 235 MPa (N/mm^2), which gives it good resistance to plastic deformation and the ductility is good, that is, it can be relatively easily bent and deformed without breaking.

Steel S235JR has a moderate corrosion resistance and needs to be protected by a layer of paint or other coating to prevent oxidation.

In terms of weldability, S235JR steel has a very good weldability, which makes it suitable for welding with different processes, such as manual welding with coated electrodes (SMEI), MIG/MAG welding, TIG welding and others [8].

Also, steel S235JR can be easily processed by plastic deformation, such as lamination, forging and extrusion.

The joints between the steel sheet plates were made by hand welding with coated electrodes, thus providingthe furnace's carcas with rigidity, mechanical strength and adequate protection for the heat treatment furnace.

The inner walls of the furnace were lined with refractory brick, a material known for its thermal insulation properties and resistance to high temperatures [9]. The use of refractory brick will help maintain a stable temperature inside the furnace and minimize heat loss to the outside, while ensuring effective protection of the outer structure of the furnace [10].

The furnace will be supported on height-adjustable legs, made of steel rods with a diameter of 10 mm, which will allow to adjust the height and level the furnace according to the working conditions.

The heat source for the heat treatment furnace will be based on cylinder gas, which allows for greater flexibility in operation and high thermal efficiency compared to other heat sources such as electricity [11].

The gas supply system will include a gas cylinder, a network of pipelines and gas flow control valves to ensure a constant and safe supply of gas to the burner [12].

In order to maintain high efficiency and reduce greenhouse gas emissions, the furnace will be equipped with a gas supercharger system, which allows an additional air flow to be brought to the burner area [13]. This will contribute to a complete combustion of gas and improve heat transfer inside the furnace.

The burner will be centrally placed in the upper panel of the furnace to ensure an even distribution of heat inside the furnace enclosure [14]. This will be a burner with stable flame and with a thermal power sufficient to reach the temperatures necessary for the desired heat treatments (annealing, normalization, return and hardening).

The air supercharger system comprises a blower that will supply air to the burner area to improve combustion efficiency and reduce greenhouse gas emissions [15]. The additional air flow rate is regulated according to the needs of the heat treatment process and the performance requirements of the furnace. The supercharger system is made of pipe with a diameter of 80 mm l, and the holes for distributing the combustible gas mixture are located on its periphery, at equal distances, being in the number of 10. The temperature control system will include an air tap that comes from the blower and that regulates the supercharging of the burner, as well as a combustible gas valve coming from the cylinder [16]. This configuration allows for effective temperature control inside the furnace, ensuring optimal conditions for heat treatments [17].

The air supply system is designed in such a way as to allow a fine adjustment of the ratio of air to gas, in order to achieve optimum combustion and effective control of the temperature inside the furnace. The adjustment of the additional air flow is carried out by means of a blower control device, which allows the adjustment of the air flow according to the needs of the heat treatment process [18].

In addition, the burner and the additional air supply system have been designed in a modular manner so as to ensure easy maintenance and replacement of the components in case of wear or defects [19]. This aspect is very important for a continuous and efficient operation of the furnace.

3. Materials and methods used in the execution of the heat treatment furnace

For the realization of the heat treatment furnace housing, the steel S235JR with a thickness of 4 [mm] was used. The chemical composition and mechanical properties of steel S235JR, in accordance with standard EN ISO EN 10025-2-2004 [20], are presented in Table 1 and Table 2 respectively.

Table 1. Chemical composition and properties of steel S235JR [20]

C [%]	Mn [%]	P [%]	S [%]	N [%]	With [%]
Max 0.2	Max 1.4	Max 0.04	Max 0.04	Max 0.012	Max 0.55

Table 2. Mechanical properties of steel S235JR [20]

R_m [MPa]	R_{eH} [MPa]	A [%]
360-510	Min. 235	24

Ptechnological vignettes of steel S235JR:

- ✓ *Weldability*: good due to its low carbon content; does not require prior heat treatment or post-welding in most cases;
- ✓ *Machinability*: good, it can be processed by chipping, forging, hot and cold rolling, bending and cutting.

To make the casing in welded construction used:

- *the type of joint*: - butt joint (for the joints of the oven frame) with the simple V-joint with an opening of about 60 degrees, which means 30 degrees for each part of the joint. This angle ensures a good penetration of the welding material and a quality joint, while avoiding excessive penetration;

- corner joint in T (for adjacent elements).

- *the addition material*: it was chosen the e lectrod of rutile type E6013, which ensures a quality welded joint and a good compatibility with the base material. This is a rutil-based sheathed electrode designed for welding low-carbon steels. The rutile coating contains mainly in its composition titanium oxide (TiO_2). It is used for the manufacture of electrodes to improve arc stability, reduce diffusible hydrogen levels and improve the appearance and quality of weld seams.

The average chemical composition of the seam made when welding with this electrode provides mechanical properties that allow the seam to withstand mechanical stress in operation without deforming, cracking or breaking.

In addition, the E6013 electrode has a low susceptibility to cold and hot cracking due to its low hydrogen content and balanced chemical composition. This makes the welded seam more resistant to the formation of cracks in conditions of rapid temperature changes (thermal cycles).

The E6013 electrode is a superfluous electrode and belongs to the category of electrodes for welding carbon steels. According to the AWS (American Welding Society) classification, the E6013 breaks down into the "E" for the electrode, "60" indicating the minimum tensile strength of 60 psi (about 410 MPa), "1" for the welding position all positions (horizontal, vertical, flat surface) and "3" indicating the type of coating.

The chemical composition and mechanical properties of electrode steel E6013, in accordance with AWS SFA 5.1 [21], are presented in Table 3 and Table 4 respectively.

Table 1. Chemical composition and properties of steel S235JR [20]

C [%]	Mn [%]	Yes [%]	P [%]	S [%]	Mo [%]	Nor [%]	Cr [%]
Max 0.2	max 1. 2	1,00	max 0.025	max 0.025	0.3	0.3	0.20

Table 2. Mechanical properties of steel S235JR [20]

R_m [MPa]	R_{eH} [MPa]	A [%]
410	Min. 330	17

The E6013 electrode is recommended for welding carbon steels in the field of their construction, shipbuilding industry, manufacture of vehicles and agricultural equipment, etc.

- electrode diameter: a diameter of 3.2 [mm] has been chosen , according to the manufacturer's specifications, for the E6013 electrode that provides the average chemical composition necessary for welding the basic material used;

- *welding current*: can have values between 100 and 140 A. Value used was 120 A, value that ensures the realization of a quality welded joint, both in terms of geometric characteristics and mechanical owners.

- *arc voltage*: it can have values between 19 and 25 V. The chosen value was 20 V has ensured the proper shape of the seam as well as the correct filling of the joint.

- *Welding angle*: can have values between 40^0 and 45^0. The value of 30 0 was chosen , a value that ensures an adequate penetration of the material and a proper filling of the joint.

- *Welding speed*: varies depending on the current and voltage of the welding, so as to ensure adequate penetration and optimal weld quality. The welding speed used was 10 cm/min.

- *pendulum of the electrode*: the optimal movement for the electrode head in this situation would be a pendulum movement combined with a rectilinear advance. This type of movement can help to achieve better penetration, uniform heat distribution and proper filling. It can be welded with good performance and directly rectilinear, without pendulum, this being the variant chosen for the execution of the case.

- *the number of passes*: depending on the width of the joint and the thickness of the material, 1-2 passes may be needed to ensure a complete weld. The one-pass welding option was chosen.

Type of equipment used for welding: an electric arc welding machine and transformer type Fronius TransPocket 150 (Fronius International GmbH, Wels, Austria) was used.

Stress relief of the welded joint: after welding, hammering was applied to the weld seam to reduce tensions and prevent cracks.

Removal of the collar: at the end the slag was removed with a metal brush to ensure a clean surface of the joint.

Control of the welded joint: the welded joints were examined optically visually and with penetrating liquids in order to identify possible imperfections occurred during the welding process.

4. Results

The heat treatment furnace was made in welded construction, with the purpose of its use in ICTI laboratories.

Following the optical-visual examination and with penetrating liquids of the welded joints, no imperfections or defects were detected that would require additional technological operations.

The heat treatment furnace carried out in welded construction is shown in Figure 1.

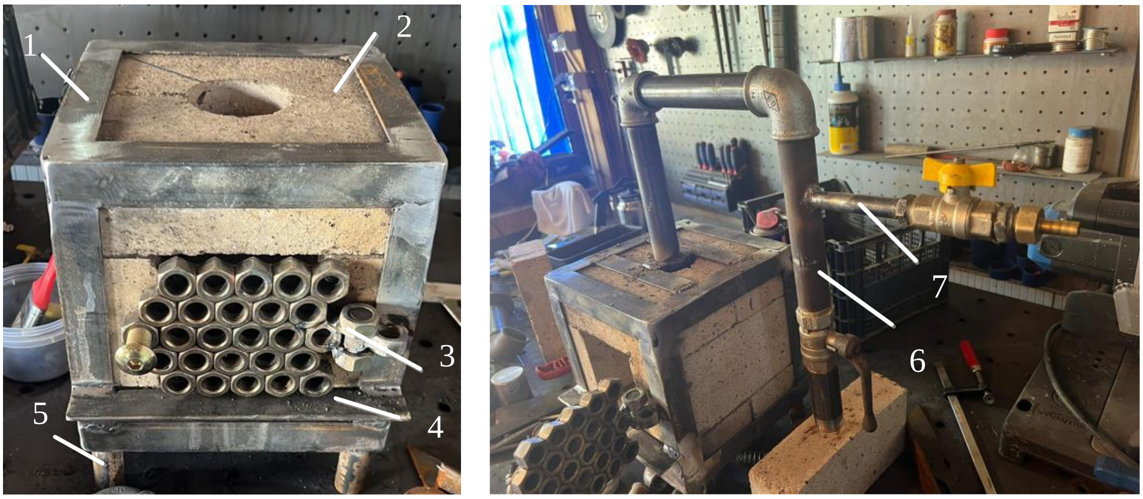

Fig. 1 Heat treatment furnace in the execution phase: 1 – metal frame, 2- refractory brick, 3- door supply parts, 4 – helper element, 5 – adjustable foot, 6 – supercharger blower, 7- gas supply route.

4. Conclusions

Following the design and construction of the heat treatment furnace, the following results and personal contributions were obtained:

- development of an efficient and versatile heat treatment furnace, able to carry out various heat treatments, such as annealing, normalization, ironing and return, for small parts in the research laboratory of the ICTI department;
- the design of a furnace that reaches the temperatures necessary for heat treatment processes and allows precise control of the speed of heating and cooling, ensuring a relatively uniform distribution of heat inside the furnace;
- the creation of an economical and environmentally friendly furnace, using a heat source based on cylinder gas supercharged with additional air brought by a blower, thereby reducing greenhouse gas emissions;
- realization of an easy-to-use and maintainable furnace, adapted for effective use in the research laboratory.

Further research directions and improvementaspects of the heat treatment furnace:

- the introduction of a system for automatic regulation of the temperature and the speed of heating and cooling, allowing a more precise control of the heat treatment process and reducing the risk of human error;
- the addition of a real-time temperature monitoring system and other relevant parameters inside the furnace, allowing users to easily supervise the heat treatment process and make adjustments as needed;
- optimisation of the gas supply and supercharger system in order to improve energy efficiency and reduce greenhouse gas emissions;
- exploring the use of other materials and technologies of thermal insulation, to further reduce heat loss and improve furnace efficiency.

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