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MODERNIZATION OF A FURNACE FOR IMPROVING TECHNOLOGICAL PROCESS FOR MAGNETIC MATERIALS SYNTHESIS

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Preparation of newly developed ferrimagnetic materials, which are the subject of various magnetic measurements, requires relatively difficult heat treatment in high temperature furnace. Firing temperatures varies in the range 900 - 1300°C. The control of a furnace has to ensure the desired time-temperature profile. This paper deals with the modernization of the laboratory chamber furnace LKO IIM - 44K produced in 1986 yet in the former GDR.

Keywords: ferrimagnetic material, heat treatment, time-temperature profile, power transformer, control of a furnace

1 INTRODUCTION

Preparation of newly developed ferrimagnetic materials with targeted properties placed ever increasing demands on their heat treatment. It is not only accurate and stable setting firing temperatures, but also compliance with the optimum time-temperature profile of the heat treatment process.

As the firing temperatures vary in the range 900 - 1300°C we need to use a high temperature furnace. Our old laboratory chamber furnace LKO IIM - 44K produced yet in 1986 in the former GDR (see Fig. 1a) was unable to meet the above requirements. Its power part was however made of highly reliable components that have the assumption to fulfil its function for a long time (power transformer), or that are available as spare parts in sufficient quantity (heating elements, see Fig. 1b).

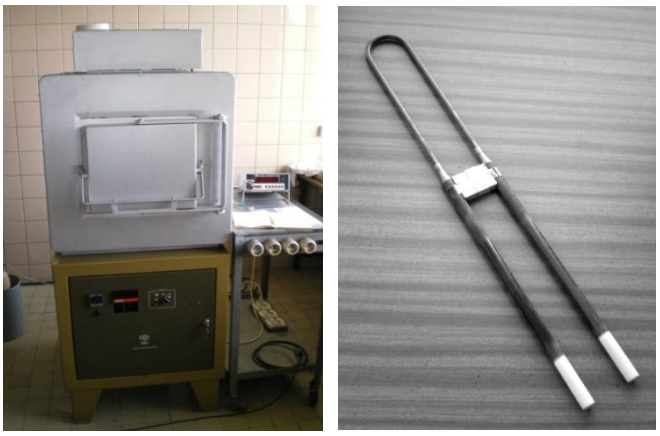

Fig. 1 From left to right: "Superkanthal" furnace and one of its disilicid molybdenum heating elements.

As a mechanical furnace design itself is very robust, the rebuilding proved to be effective and very economical.

2 GOALS OF THE MODERNIZATION

A subject-matter of the modernization was replacement of three-stage contactor furnace power control with a "continuous" one, by means of thyristor unit with phase angle control of supply current to power transformer, which secondary is connected to the heating elements.

Fig. 2 From left to right: PID controller and timer with real-time clock.

The old two-position temperature controller was replaced by modern one with PID technology and with the possibility of adjustment ramp parameters of increase, respectively drops of the temperature (see Fig. 2a).

For the purpose of automatic turn on, respectively off of the furnace if the operator is not present was in the power management of its control integrated a timer with real-time clock (see Fig. 2b).

3 SOLVING SOME FUNDAMENTAL PROBLEMS

During the solution of this modernization it was necessary to solve some fundamental problems. As the furnace heating elements are used so called "superkanthal" loops based on disilicid molybdenum with operating temperature up to 1600°C.

3.1 Limitation of current in heating elements

The strong temperature dependence of resistance of the material of heating elements requires the limitation of current within operating temperature to 500°C. In the original connection it was ensure by trio of contactors connected to the power transformer primary taps. Used thyristor unit connected to those with lowest transmission ratio has the option of analog current control over the in-

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put labelled "external current limit profiling", which is connected to the relevant output of the controller supplying in suitable adjusting temperature range linearly variable control voltage.

3.2 High inrush current

Another problem is the high inrush current at turn on of the cold oven, which causes frequent blowing of ultra rapid fuse necessarily used to protect power thyristors of the unit themselves.

3.2.1 REAL TRANSFORMER GENERALLY

In a real transformer (see Fig. 3) there is a power dissipation and flux dissipation.

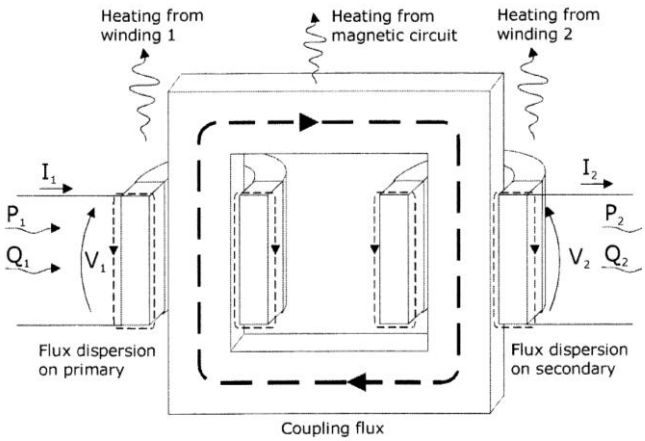

Fig. 3 Real transformer.

If we consider the principle of preservation of energy and in first hypothesis we don't consider power loss

$$P_1 \cong P_2\ (W) \tag{1}$$

and

$$Q_1 \cong Q_2\ (VAr) \tag{2}$$

Voltage ratio and the reciprocal of the current ratio are the same

$$\frac{V_1}{V_2} = K = \frac{I_2}{I_1}\ (V, A) \tag{3}$$

3.2.2 LOADED TRANSFORMER

If the secondary of transformer is closed on a resistive load R_L, the equivalent circuit we can see in Fig. 4.

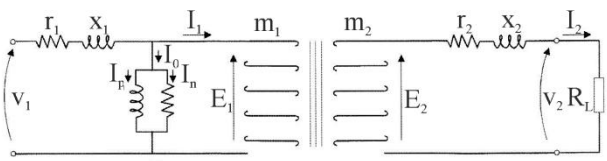

Fig. 4 Loaded transformer

If we assume $K = \frac{m_1}{m_2} = 1$ the unloaded transformer seen by thyristor unit is in Fig. 5. In this case the load is mostly resistive and the power factor is equal 0.8 ÷ 0.9.

We have measured the resistance of cold heating elements R_L and its value was by 20°C very small, about 20 mΩ. Thus we can say that the transformer is working practically in short circuit. Short circuit voltage V_{SC} is the value of voltage on primary able to give a circulating current equal to nominal with the secondary terminals in short circuit. In normal transformer it is 5% of V_1.

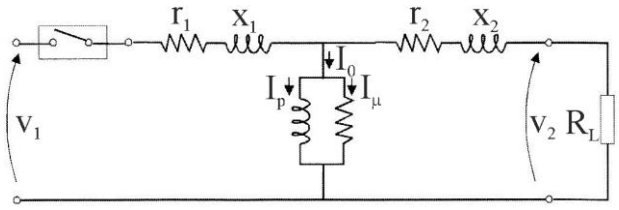

Fig. 5 Loaded transformer with winding ratio equal 1.

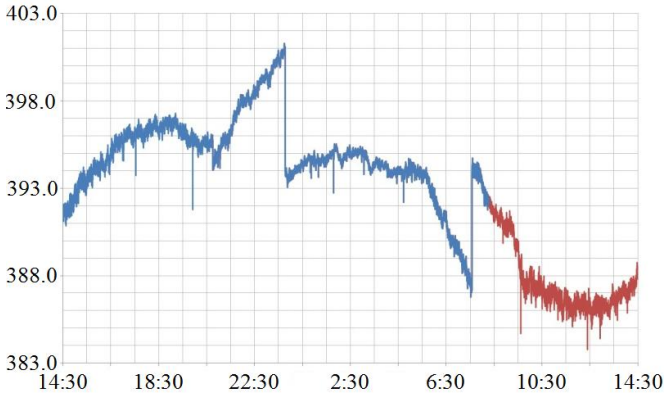

Fig. 6 Phase-phase mains voltage within 24 hours.

Fig. 7 Ultrarapid fuse.

However, this means that if is done a short circuit on secondary (cold start) with nominal voltage on primary the circulating current becomes 20 times the nominal one. The current is limited only by impedance of primary and secondary winding and leakage inductance is equivalent to an air coil – it doesn't saturate [1, 2].

This current is of course dependent on the mains voltage too and was on the limit of the prescribed fuse breaking current.

After all week mains voltage monitoring (see Fig. 6), we finally decided to use one step more powerful thyristor unit, which uses also a larger ultra rapid fuse (50 A versus 32 A, see Fig. 7).

3.3 Control optimizing

The last problem that we had to solve was to optimize the PID control variables, responsible for its stability. Optimal parameters were determined experimentally during the test operation of the furnace [3].

4 CONCLUSIONS

Over the past two years we have with minimal cost successfully upgraded our old high temperature furnace, which now complies with its parameters requirements on preparation of newly developed ferrimagnetic materials. Coincidentally, the last year we managed to get the money to buy new furnace with similar parameters, and so we can compare. Except for the possibility of direct communication with the computer and application a little better (more modern) insulation are all remaining features of the two furnaces almost identical.

Acknowledgement

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