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PC INTEGRATED INSTALLATION FOR STUDYING OF THE COOLING ABILITY OF FLUIDS FOR HARDENING AT LOWERED PRESSURE (VACUUM)

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The vacuum thermal processing has a significant place in the practice of the thermal processes mainly for the instrumental and special steels.
There is a center for vacuum thermal processing and chemical heat treatment at RU "Angel Kanchev". The studying of the cooling (quenching) at lowered pressure (vacuum) with the existing technical instruments is very difficult.
The aim of the paper is to introduce the construction, operation and the means of installation, connected with PC, for studying the cooling ability of quenchants.
The installation consists of the following main elements: a heating camera, a cooling camera, a controlling device, a vacuuming system, feeding and a registering part. The latter contains PC software, processing and introducing in table and graphic form the main characteristics of the quenching of the sample in the fluid "T – t" (temperature – time) and "CR – T" (cooling rate – temperature), and an analog-digit converter (ADC).
The installation gives the possibility of determining the cooling ability of liquid and gaseous fluids. The temperature of heating of the sample and the fluid, the pressure (vacuum), the agitation of the quenchant, and some other factors can be changed in it.
Important dependencies, explaining the influence of the main factors (parameters) of the cooling ability of each fluid, can be determined by means of the installation. The controlling process of the quenching at lowered pressure (vacuum) and the minimizing of the refuse during the practical realization of the operation are thus made possible.

Key words: Heat Treatment, Quenching, Vacuum Quenching, Vacuum Installation, Cooling Ability of Quenchants.

INTRODUCTION

The quenching of workpieces made of constructional steel (ferrito-pearlitic or pearlitic class), after heat treatment or chemical heat treatment in vacuum obtain lower hardness than that conventional quenching at atmospheric pressure. If gas quenchant is used, the lower hardness is explained with the lower number of thermophores per unit of volume in a vacuum-cooling chamber. The use of liquid quenchants for vacuum quenching shows similar trend – lower hardenability of the above mentioned steels. This effect is a disadvantage of the vacuum quenching, so the reasons that causes it and the factors that influence it shall be established.
The aim of this paper is to introduce the structure, basic components and opportunities of a system, adapted to PC for studying the cooling ability of liquid quenchants in vacuum.

PRESENTATION

The published data about the cooling ability of the liquid quenchants under subatmospheric pressure is not sufficient [3]. A possible reason for this is the scanty information on specialized systems for receiving and registering of cooling curves.

Such a system has been designed at the University of Rousse [1, 2]. Its arrangement and basic components are shown on Figure 1.

The cooling ability of the quenchants is studied by using a sample (1). Its size and shape could be designed in accordance to the examiner's wishes. The sample form is recommended to be close to the form of the typical constructional steel workpieces subject to vacuum quenching. In this system the sample has the form of a rotational ellipsoid – a body that provides conditions for optimal fluid streamlining. It has been made of copper, electrolytically coated with iron and consequently carbonized. This approach allows combining a working surface simulating steel with a core possesses high thermal conductivity. A thermocouple "chromel-alumel" is welded close to the surface, under the steel coating. The sample is heated up to T_h=850°C in the heating chamber (2), using a cylindrical graphite heater, placed equidistant to the sample. The heater is fed by adjustable voltage source U=18÷24V with power P=50kW (6). The cooling chamber (3) is placed below the heating chamber. The sample enters through a vertical movement downwards. The basic component of the chamber is the tank, containing the investigated liquid, having a volume of 1.5 dm^3. The liquid is agitated by a propeller and heated by a heater. The liquid temperature is measured and controlled using a thermocouple "copper – constantan". There is also an opportunity for tank cooling.

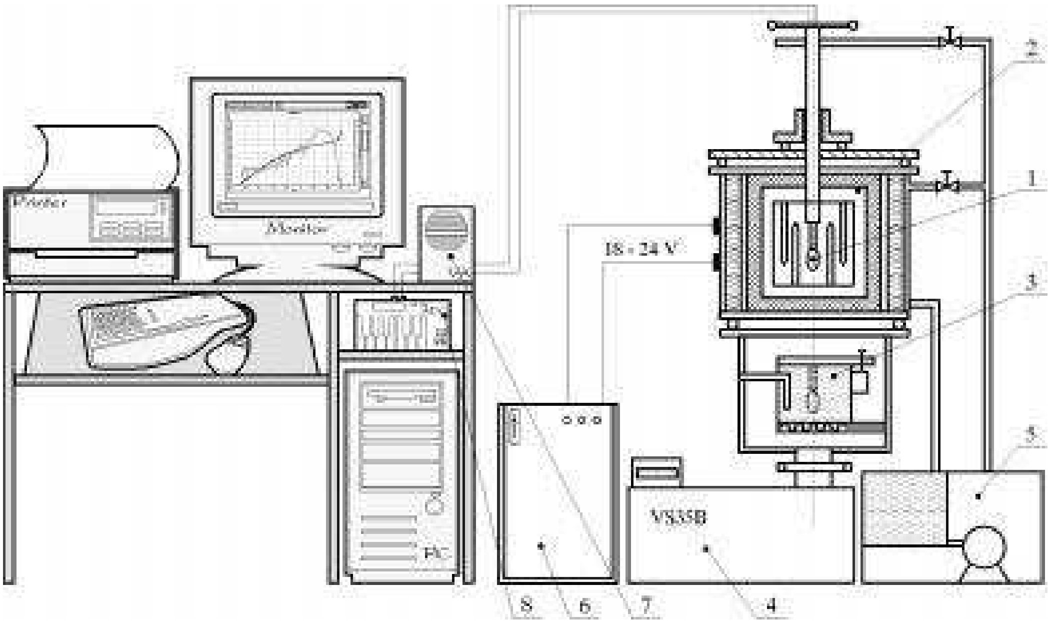


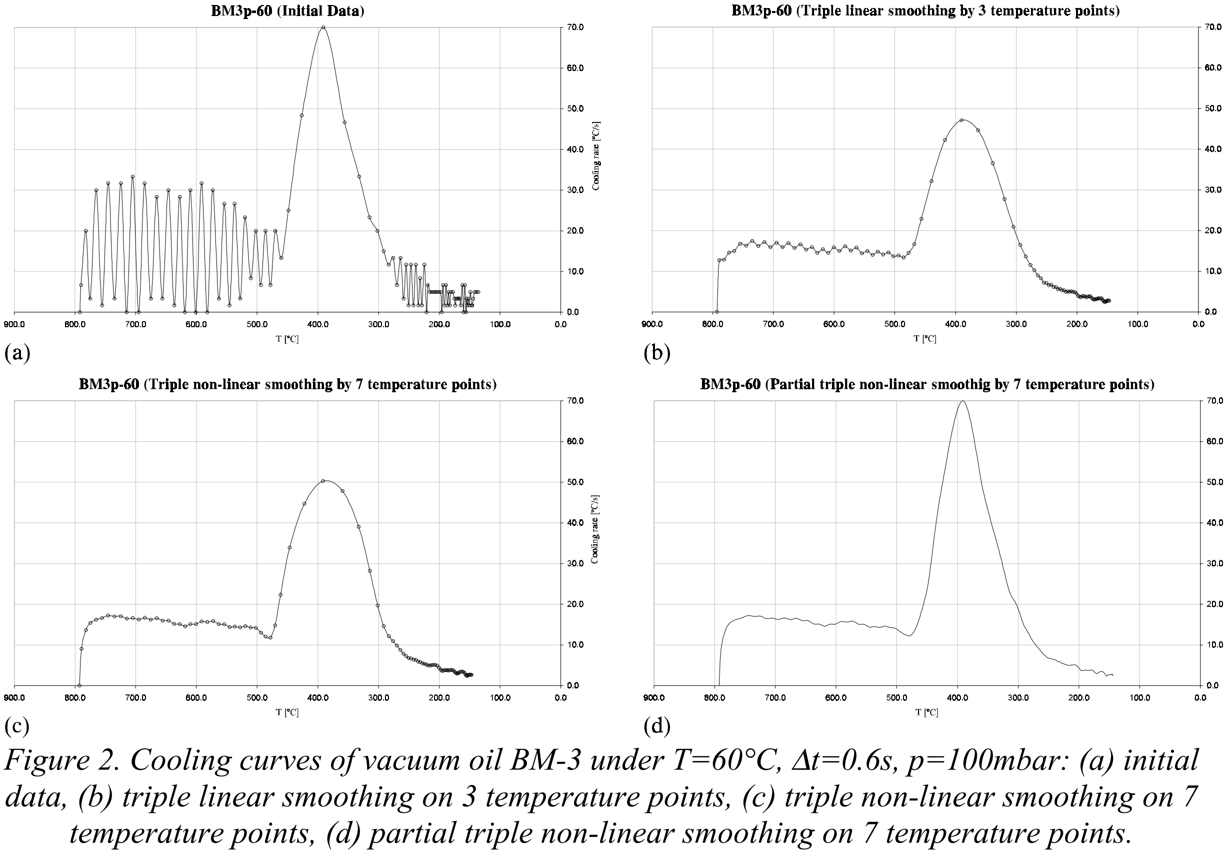
Figure 1. System for investigating the cooling capability of liquid quenchants in vacuum

The system (Fig. 1) also includes: a vacuum system (4), a tank containing cooling water (5) which provides the cooling of the heated components of the system, a thermoelectromotive voltage amplifier (from the thermocouple of the sample) (7) and an analogue-to-digital converter (ADC) - (8).

The primary information about the cooling ability of the studied quenchant is the change of the sample's temperature as a function of time. A device for amplifying the signal from the thermocouple of the sample has been developed ($K_{ampl}\approx250$). The signal, coming from the thermocouple, is corrected in the non-linear ranges of the thermocouple characteristics. The analogue signal is converted through the ADC and the connection with the PC is done through the block PIO24II, produced by "BMC Mess**systeme**" (Fig. 1). The program DataTemp, written on TurboC, controls the conversion and signal transmission process from the sample to the PC.

The carrying out of each test requires determining the initial and end temperature for recording and the time interval between two successive temperature readings. The recorded file is processed through standard program products (Microsoft Excel, Maple, etc.) in order to obtain the graphic dependencies.

Precise temperature reading is premise for the assessment of cooling of the sample in quenchants. Unfortunately, the process is characterized with a variable dynamics, which is a result from the several cooling stages. The requirement for decreasing the time interval between two temperature readings contradicts the accuracy of its measuring. This disadvantage could be eliminated through increasing the number of repeated tests, but it requires much time, especially when testing is done under decreased pressure (vacuum). Another opportunity is filtration and primary data processing T= f (t). That processing smoothes the curves without eliminating the influence of specific transition statuses and without size deformation of the adopted assessments of the pearlitic and martensite temperature intervals.



(a) (b) (c) (d)

Figure 2. Cooling curves of vacuum oil BM-3 under T=60°C, Δt=0.6s, p=100mbar: (a) initial data, (b) triple linear smoothing on 3 temperature points, (c) triple non-linear smoothing on 7 temperature points, (d) partial triple non-linear smoothing on 7 temperature points.

The primary data smoothing is done by two methods – linear and non-linear [2, 4]. It also can be applied just for parts of the curve T= f (t). The required smoothness of the studied curve part could be obtained after a different number of iterations. Following that primary processing, differentiation and calculation of other characteristics of heat transfer is done.

Figure 2 shows initial (a) and triple smoothed (b, c, d) cooling curves of vacuum oil (BM-3).

Partial smoothing is applied to the vapor blanket phase (800÷450°C) and convective heat transfer (300÷100°C). The comparison between the non-processed and processed curve shows the smoothing of the curve; the similarity is maximal after partial non-linear smoothing on seven points.

The absolute and relative differences between initial and processed data are shown in Table 1.

Absolute and relative differences between initial and processed data. Table 1

Initial value	Triple linear smoothing	Triple non-linear smoothing	Partial triple non-linear smoothing		
15.5	15.3	15.3	15.4	[°C/s]	CR_p^{av}
	-1.5	-1.1	-0.8	-	Difference %
7.7	7.2	7.0	7.5	[°C/s]	CR_m^{av}
	-6.7	-9.7	-2.1	-	Difference %
70.0	47.1	50.3	70.0	[°C/s]	CR_{max}
	-32.7	-28.1	0.0	-	Difference %
391.0	390.7	391.6	391.6	[°C]	$T(CR_{max})$

The table shows that the accuracy of processed data is satisfactory.

CONCLUSION

The developed system for studying the cooling ability of liquid quenchants in vacuum contributes to further examinations of vacuum oil quenching properties.

The adapting of the system to PC and the developed program products make the processing of the quenching characteristics easier. The adopted methods for filtration and smoothing of the received temperature data create preconditions for decreasing the number of tests. The accuracy of the quantitative assessments of the cooling ability of liquid quenchants in vacuum is satisfactory.

LIST OF SYMBOLS

CR_p^{av}	Average cooling rate in pearlitic temperature interval (650÷550°C) [°C/s]
CR_m^{av}	Average cooling rate in martensite temperature interval (300÷200°C) [°C/s]
CR_{max}	Maximum cooling rate [°C/s]
$T(CR_{max})$	Temperature of registration of the maximum cooling rate [°C]
BM-3	Vacuum oil made in Russia

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