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Automation of Vision and Transportation Modules, Implemented in the Thermo-Wet System

1. Introduction

Thermo-Wet is an automated test stand designed to determine the physical and chemical properties of materials in a wide range of temperature from 650 °C – up to 1700 °C [1]. The stand is equipped with a system capable of generate gas protective atmosphere of the presence of Ar, N, as well as a protective-reducing atmosphere H_2.

Block diagram of measurement system device is presented in Figure 1. The main equipment modules are: stove with an arrangement of power (1), temperature controller (2) vision system (3), PC card frame-Graber type (4).

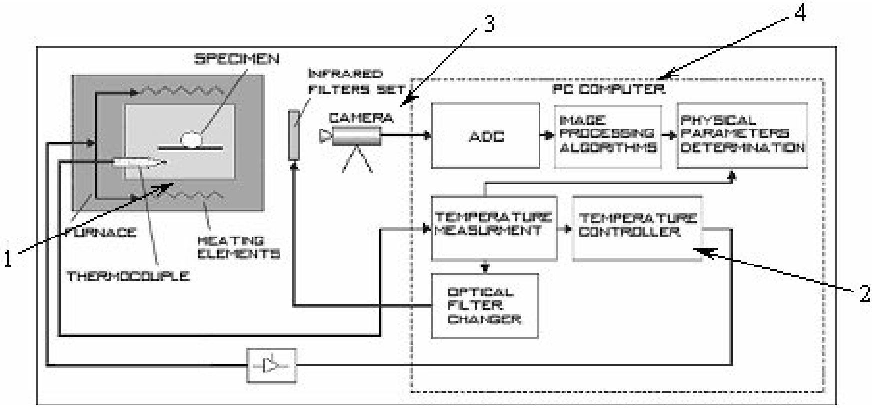

Fig. 1. Block diagram of measuring system

Physicochemical values to be determined using Thermo-Wet devices are surface tension and contact angle. Determination of the contact angle is a direct measurement method based on a point of contact of three phases, according to the definition Young's

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equation (1) [2]. The second factor is determined on the basis of the experiments, according to Porter's equation (2) [2]. Equilibrium conditions of constant drop on the plate are shown in Figure 2 [3].

$$|\bar{\sigma}_{LV}|\cos\theta + |\bar{\sigma}_{SL}| - |\bar{\sigma}_{SV}| = 0 \tag{1}$$

where:

- θ – contact angle,
- σ_{SV} – surface at the border of solid – gas,
- σ_{SL} – surface tension at the border of solid – liquid,
- σ_{LV} – surface tension at the order of liquid – vapour.

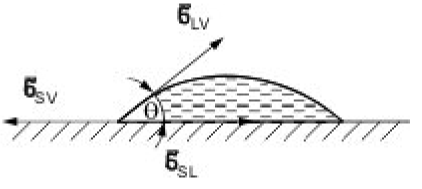

Fig. 2. Physicochemical parameters of the sample

Geometric parameters determined by the drop-processing algorithm are illustrated in Figure 3.

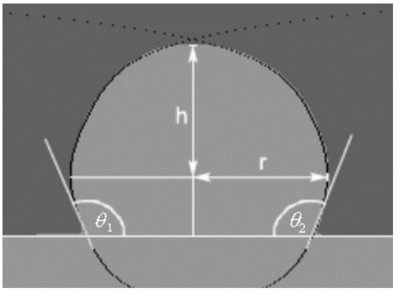

Fig. 3. The measured geometrical parameters of the sample
(r – the maximum radius of the droplet, h – height of drop of the equatorial plane;
θ1, θ2 – left and right contact angle)

The value of surface tension was calculated on the basis of the experimental Porter's equation (2).

$$\frac{\alpha^2}{r^2} = \left(\frac{h}{r}\right)^2 - 0.660\left(\frac{h}{r}\right)^2\left[1 - 4.05\left(\frac{h}{r}\right)^2\right] \tag{2}$$

where:

r – the maximum radius of the droplet,
h – drop height above the equatorial plane,
α – capillary constant.

Specific value of the drop's radius and height enables the designation of the capillary constant value. Taking into account the density of the material, the gravitation and the capillary constant, the surface tension is calculated basing on the expression (3).

$$\sigma = g\Delta\rho\alpha^2 \tag{3}$$

where:

$\Delta\rho$ – difference in the density, in the case of metal and gas phase practically: $\Delta\rho - \rho_S$, where being ρ_S is the density of metal,
g – acceleration due to gravity,
α^2 – determined from the empirical Porter's formula (2).

Measurement of surface tension is carried out on the ground, which is not wetted by the test material (Fig. 4) [6, 7]. To determine the value of surface tension only the upper part of the drop is analyzed (from the equator to the top of the drop).

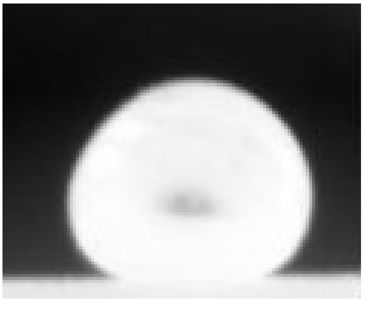

Fig. 4. Views of liquid metal drops on the not-wetting substrate

However, the contact angle measurement is carried out by completely other methods (only the lower part drops is analyzed). In the case of angle measurements in certain conditions, implemented authors' algorithms accurately determine the value of searched value. In the case of measuring the dynamics of wetting systems with good wettability (Fig. 5) there appear some difficulties with the location of contact point of three phases.

The tested liquid metal can move on the ground in different directions, with different speed. The dynamics of this phenomenon is a function of many variables, considering the thermodynamic aspect, which is connected with lowering the surface free energy, but also depends on the basic parameters such as the state of the surface of the substrate.

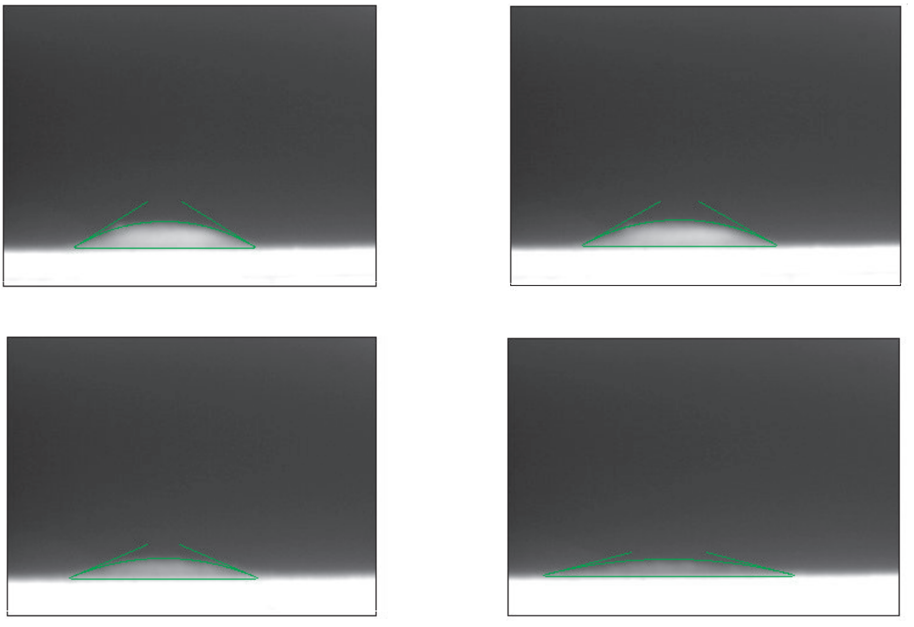

Fig. 5. Views of liquid metal melting on the well wetting substrate

2. The concept of Thermo-Wet modernization

One of the basic modules of the Thermo-Wet device is vision system shown in Figure 5. It consists of several main components: the camera mounting system, a set of infrared filters, CCD camera with zoom lens [7, 8]. The experiments show that the use of cameras with higher resolution definitely improves the quality of the obtained results (Tab. 1). Still the difficulties connected with the possibility of a smooth transition of the vision system's position, make the expansion of the measuring range impossible. The studies carried out have revealed a number of drawbacks in the design of the vision system. The main limitation of the current solution is the lack of precise positioning of the camera [6].

Table 1
Summary of results

Surfach tension [N/m]		
Camera Watec 320x240	Camera Jenoptic 694x516	The reading Literature
1,3133	1,1513	1,2
~ 9,4	~ 4,0	Relative error [%]

The lack of information on the current position of the camera in regards of the material point or the base point makes it necessary to correct the depth of field which directly affects the deterioration of results. Calibration system based on the vision system model is imprecise and inconvenient to implement. This causes the application of an element with high accuracy execution order of 0.005 mm while maintaining a small overall dimensions. Obtaining accurate picture calibration is possible with the use of distributed artificial lighting inside the furnace chamber, which lengthens and complicates the measurement process. Camera mounting system limits the use of cameras with different focal lengths than previously assumed (Fig. 6).

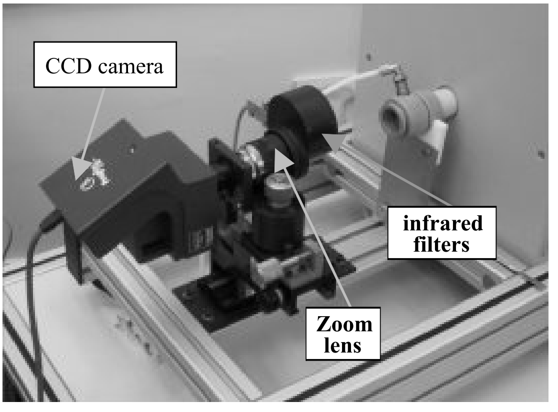

Fig. 6. Vision system

Many years of experience measurement, revealed a number of possible changes in the mechanical construction, as well as in the software of Thermo-Wet device, which will automate the entire measurement process. Current modernization of equipment Thermo-Wet is achieved in the framework of the KBN grant No. N N519 403037 entitled: "Modern algorithms for image processing and analysis in the measurement of surface tension and contact angle of materials at high temperatures". Within the frames of the system reconstruction, a completely new design of the vision system has been proposed (Fig. 7). The system will move in three planes independently, the dislocations will be carried out through the system: stepper motor, screw balls, the end position sensors. Minimum feed rate of the video in each of the planes is assumed at the level of 0.01 mm. An algorithm for the system is designed to allow for automatic, optimal focus (autofocus) implementing.

Another module to be modernized is the charging-discharging system. There has been suggested a solution ensuring accurate positioning of table settings in the horizontal and vertical plane surface (tile of the tested floor). Both the feed rate and residence time of the sample in the initial and basic chamber will be governed by the software. Forcing the movement of the table will be implemented as in the case of the vision system: stepper motor, screw balls, the end position sensors (Fig. 8).

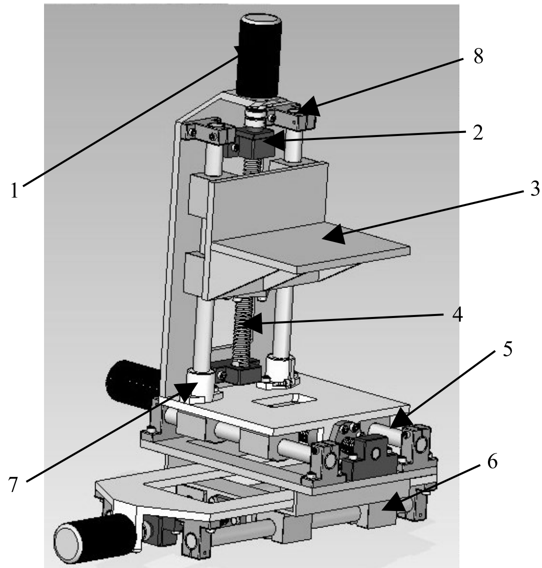

Fig. 7. Designed vision system (1 – stepper motor, 2 – bearing block rack (drive side), 3 – table camera, 4 – screw bullets (Train), 5 – fence, 6 – linear bearings in the housing, 7, 8 – handle)

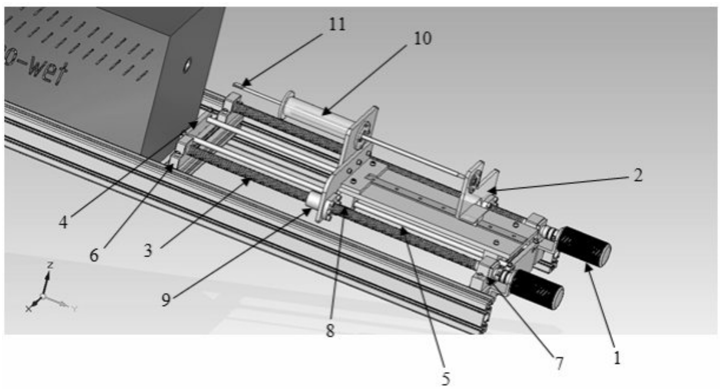

Fig. 8. Designed charging-discharging system (1 – stepper motor, 2 – base, 3 – screw bullets (Train), 4 – supporting block fence, 5 – linear guide, 6 – bearing block rack (site maintenance), 7 – bearing block rack (drive side), 8 – linear bearings in the housing, 9 – nut bullets, 10 – prechamber, 11 – measuring table)

3. Conclusion

The proposed modernization of Thermo-Wet will provide full automation of the measurement process. This will allow for high quality results and their repeatability. Maintaining the same boundary conditions of the experiment will allow for their comparison with different variants assumed, then the optimal choice that meets the criteria taken.

In addition, automated measurement of tested values is a fast and accurate verification of the materials used in the technological process. The modular construction of the device allows for testing materials of different properties and uses. Moreover, software architecture allows for its easy upgrading depending on the user's needs.

Reference

[1] *Automatyczne pomiary napięcia powierzchniowego i kąta zwilżania materiałów w wysokich temperaturach.* Projekt badawczy: Nr 8 T10C 005 14.
[2] Missol W., *Energia powierzchni rozdziału faz w metalach*. Wyd. Śląsk, Katowice, 1974.
[3] Wieloch S., *Krzepnięcie metali i stopów*. Ossolineum, Warszawa, 1988.
[4] Strona internetowa firmy Watec: *http://www.watec.net/*.
[5] Strona internetowa firmy Jenoptik: *http://www.jenoptik.com/*.
[6] Ferenc K., Nita Z., Sobiś T., *Spawalnictwo*. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 1999.
[7] Moser Z., Gąsior W., Struś J., *Surface-tension measurement of the eutectic alloy*. Journal of Electornic Materials, t. 1, nr 11, 2002, 1225–129.
[8] Włosiński W., *The joinnig of advaced materials*. Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław, 2000.