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A procedure to monitor the critical aspects of the sampling in the authenticity tests by TL

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Abstract. This work addresses a contribution to specific objectives of a wide research project aimed at making operator-independent and at having an automatic system during the collection phase in authenticity test by Thermoluminescence. Here we dealt with critical aspects of the sampling regard the temperature monitoring during the drilling. A homemade system is built up to carry out the experiments and allow assessing correlation between the temperatures evaluated by elaboration of thermal images and the values of force measured from 5N to 30N in correspondence of hole generated in the brick and of the drill bit.

1. Introduction

This paper represents an improving step in a multidisciplinary project aimed at upgrading the collection phase and at establishing the best procedure in the authenticity tests by Thermoluminescence [1-3] of ceramic and terracotta artifacts. In these tests, the sampling represents a fundamental step in which the temperature reached by the sample during the drilling is important, as already assessed in previous research articles. In [4] a preliminary research, based on a non-invasive and in situ measurement methodology, has been presented. The proposed method allowed estimating thermal energy dissipated during the drilling through the measurement of an output voltage in different conditions [4]. The obtained results have been validated in [5] using a standard direct method based on thermal images acquisitions. In this case, the IR thermograph imaging has been coupled with electrical measurements and a relationship between the electrical measurements with the thermal conductivity was assessed. The model was implemented and correlated with information about the effects of the temperature reached during drilling in terms of TL signal loss by simulations [6]. If the sample reaches high temperatures during drilling, the experimental signal is not correlated to the elapsed time and then to the age of the artifact.

In this occasion the development of a procedure useful to monitor the pressure applied with the drill on the surface of the sample is presented. The aim is to obtain a device useful to give an alert to the operator if a dangerous temperature for the TL test. By a homemade system assembled in laboratory, the force applied on the specific area of the drill bit was measured in a specific time interval. At the surface of the brick sample at the end of the drilling, IR images were acquired for obtaining the maximum temperature reached by the sample [7-8].

The relation between the temperature and the force is well known [9] and it was experimentally verified. This was important to lay the basis for the development of a sensor device that, placed on the drill, could notify the pressure and the temperature reached during the sampling to the operator.

Knowing, in fact, the surface on which the force is applied, calculated considering the drill bit, the pressure is obtained.

Even if the conditions performing during the collection phase depend on several factors above all the intrinsic characteristics of the sample and the directives of the artifact owner to preserve the object, by the working principle of the dispositive here presented, it could be possible to get in advance a series of fundamental information to evidence any criticisms and the potential need of opportune corrections to the luminescence measurements results.

2. Experimental

Samples of brick with characteristics like density and porosity representative of pottery sherds usually subjected to authenticity tests have been used to conduct the experiments. An expressly designed system for the present study, shown in Figure 1, is realized to allow drilling the sample and at the same time acquires the force and the IR images.

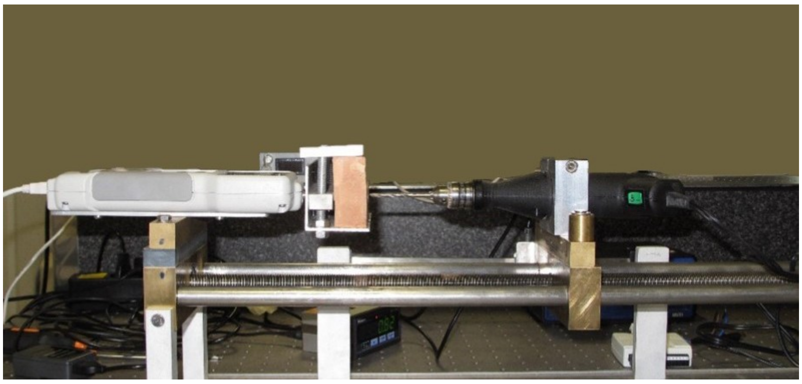

Figure 1. The homemade system designed for the experiments.

The drilling is realized by a high precision Minicraft drill MB1012. The infrared thermography is used to evaluate the temperature reached by sample at the end of the drilling step. The thermal imaging camera FLIR® System B series with a spectral range of 7.5-13 μm and a measurable temperature range from -20 °C to +120 °C was used. The measurements were performed with controlled temperature (22 °C) and humidity (30%) at a fixed relative distance between camera and sample of 60 cm. The IR images are processed by the ThermaCAM Researcher basic 2.8 SR-1 software. The force is measured by an IMADA ZP-1000N digital dynamometer with a precision of ± 1 N.

In the experiments, the time is set at 30 seconds during which the force is maintained constant thank to the controlled system. Increasing values of force are applied from 5 N to 30 N to the drill on the brick surface, using a drill bit of 4 mm. At the end of each drilling step, the IR images have been acquired and the temperatures of the hole surface and of the drill bit have been registered considering specific values of emissivity [9-10].

3. Results and Discussion

The system expressly designed for the present study allowed to maintain quite constant the applied force during the drilling. As example of this assumption, for the 20 N force, in Figure 2, a graph reporting the values of force measured during the 30 seconds of drilling has been shown.

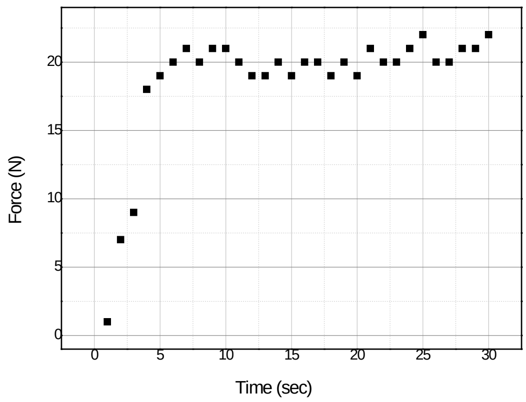

Figure 2. Values of force (N) during the 30 seconds of the sampling phase simulated in laboratory.

At the end of each drilling phase, the IR images were acquired, and the temperature data were obtained considering the maximum value in a ROI (Region Of Interest) placed in the center of the hole, as shown in Figure 3.

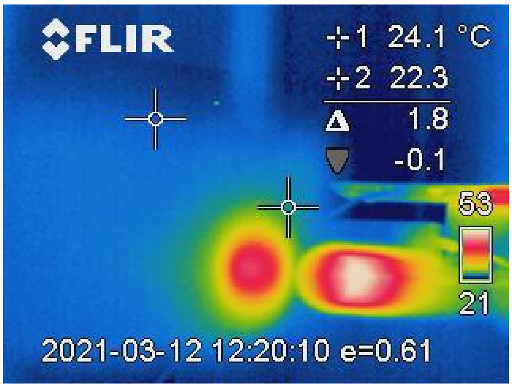

Figure 3**.** IR image processed by ThermaCAM software and ROI including hole and drill bit. The drill bit and the hole have dimensions of 4 mm.

The temperature information acquired by processing IR imaging was used to correlate it with the measured force. In Table 1, the average values calculated from repeated measurements of force and temperatures obtained from IR thermograph analysis are listed. The temperatures of the hole generated on the brick surface by the drill and of the drill bit have been shown.

Table 1. For the set time of 30 seconds, the values of applied force and the temperature, obtained by IR thermography, of the hole on the surface of the brick sample and of the drill bit used during the collection phase.

Time (sec)	Force (N)	Surface hole max temperature (°C)	Drill bit max temperature (°C)
30	5±1	25±2	27±2
30	10±1	29±2	35±2
30	20±1	43±2	55±2
30	30±1	45±2	57±2

The maximum temperatures reached during the drilling have been plotted against the applied force and a correlation is found and shown in Figure 4. This correlation regarded both the temperatures measured on the surface of the brick and of the drill bit. Increasing the applied force, the temperatures augmented until reaching a plateau at 30 N.

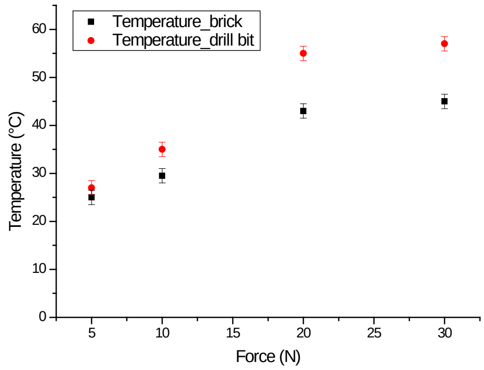

Figure 4. The correlation between the temperature (°C) evaluated by elaboration of thermal images and the values of force measured from 5 N to 30 N in correspondence of hole generated in the brick and of the drill bit.

Conclusion

The results allowed to establish that it is possible to predict, for a specific force applied with the surface of the brick and knowing the area of the drill bit, the pressure enough to not reach dangerous increasing of temperature during the collection phase in an authenticity test. Thanks to this, it is possible to think to equip the drill with a smart device that indicates when a specific value of temperature is reaching.

The perspectives regard the temperature measurements in the brick sample and not only on the surface, by using an intelligent drill tip with an embedded pressure sensor in order to estimate the temperature during the drilling procedure.

Furthermore, the shape of the tested archaeological or artistic objects will be considered in order to take in account their variability with the aim to design a versatile sampling device.

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