Termal Kamera Görüntüleriyle Kalsiyum Sülfat Çimentonun Donma Sürecinin Değerlendirilmesi

Evaluation of Calcium Sulphate Cement Setting Process Based on Thermal Camera Images

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***Özetçe*—Bu çalışmanın amacı, ortopedide ve implantlarda kullanılan Kalsiyum Sülfat bazlı alçıların donma sürecini Vicat Testinden farklı yöntemler kullanarak gözlemlemektir. Bu amaçla, farklı Kalsiyum Sülfat bazlı alçılar farklı oranlarda hazırlanarak, hamurların donma süreci Vicat testi, termal kamerayla sıcaklık kaydı ve kütledeki değişim şeklinde kaydedilmiştir. Örneklerin sıcaklığında artış ve kütlelerinde azalma tespit edilmiş, alçıların farklı hızlarda, ekzotermik reaksiyonla donduğu görülmüştür. Örneklerin sıcaklık haritaları elde edilerek, her bir pikselin sıcaklık değeri belirlenmiştir. Sıcaklık haritaları çıkarılması sırasında, renklerin sıcaklık değeri olarak karşılığı, her bir farklı görüntü setine özel bir algoritma kullanılarak kalibre edilmiştir. Uygulanan görüntü işleme tekniklerinden elde edilen sonuçlar kullanılarak, reaksiyonun ekzotermik bir süreç izleyerek, içten dışa yayıldığı gözlemlenmiştir.**

Anahtar Kelimeler— Kalsiyum Süfat çimento, donma sıcaklığı, donma süresi, görüntü işleme yöntemleri, termal kamera.

***Abstract*—The purpose of this study was to determine alternative methods for cement setting and examining the outcome using image processing techniques. The Vicat Test setting time results of cement pastes prepared from fast and slow drying Ca-S cements were compared with alternative examination methods involving mass and temperature change using a thermal camera. The results indicate that with cement setting, a correlating increase in sample temperature with a loss of mass is observed, indicating that cement set at differing rates via an exothermic reaction. Temperature values for each pixel were determined and temperature maps of samples were obtained. Temperature scales of maps were calibrated using a special algorithm. The results of image segmentation techniques applied indicate that the reaction process is exothermic. With cement setting, a temperature increment spreading from the inner to the outer boundaries of cement paste was observed.**

Keywords — Calcium Sulphate cement, setting temperature, setting time, image processing, thermal camera.

I. INTRODUCTION

The 'Plaster of Paris', widely used in orthopedics, is a hydrate form of gypsum, converted to Calcium Sulphate hemihydrate with moderate heating. The Calcium Sulphate cement setting time and consistency may be determined by the Vicat Test, which is applied on cement paste placed in a conical holder using a needle, which is dropped to penetrate the cement surface at regular intervals [1].

In this study, setting time of fast and slow setting Calcium Sulphate (Ca-S) cements, mixed at various ratios is evaluated. In addition to the conventional Vicat Test, based on the exothermic nature of this setting reaction an alternative method, involving detection of mass loss and heat release [2,3] combining with image processing techniques is proposed.

II. MATERIALS & METHOD

In this study, slow (S) and fast (F) Ca-S cement, mixed at different ratios was used. The slow setting Ca-S cement is commercially used as an undercoat for all painting surfaces, filling the gaps, correcting the edges, eliminating the surface defects and creating a smooth surface. The fast setting Ca-S cement is commercially used as a fire-resistant material, ensuring sound and heat isolation. S and F Ca-S cement powders were mixed at ratios of 1:9 (1S:9F) and 1:12 (1S:12F) at a final powder to liquid ratio of 30:13 (g/ml).

The setting time for the Ca-S cements was determined conventionally using the Vicat Tester, where the samples were prepared and placed in the conical holder of the Vicat apparatus, the top of the mold was smoothened, a 1-mm needle with 300 g weight was placed over the mold surface, the consistency plunger was squeezed to drop the needle every 30 seconds and the value on the Vicat's ruler was recorded until the needle is not able to further penetrate the cement. The needle of the Vicat apparatus was cleaned after each test.

An alternative method involving the use of a thermal camera and precision balance was used to determine the setting time. In this combined method, setting time was determined as a function of temperature change and mass loss. The Ca-S cement paste was molded into a petri dish and its surface was flattened. The petri dish was then placed on a precision balance across from a thermal camera (FLIR E6) at a distance of 6.5 cm, enabling the recording of both temperature and mass change every 30 seconds up to termination of the experiment at 20 minutes.

All tests were conducted in triplicates; data was evaluated statistically and compared. The thermal camera images were evaluated using image processing techniques to determine the setting process of Ca-S cements. The data sets containing thermal images of samples were read on Python interface for image segmentation. The RGB images were converted to greyscale (Fig. 1) to simplify the imaging process [4]. The thermal images obtained were observed using image processing tools of Python software equipped with image processing modules. Using these modules and the pre-defined functions, a special algorithm was created to calibrate temperature values of greyscale images. After calibration, the graph of mean temperatures of ROIs were obtained. The temperature difference on cement surface was evaluated as a 2D image and repeated for each sample for 80 slices. The 2D slices were then converted to 3D matrices and calibrated under the same color bar showing the maximum and minimum temperatures. For each data set, regions of interest (ROIs) were determined with minimal data loss. For each ROI, temperature maps per slice (Fig. 2) as well as the average temperature of each slice were obtained. The time-based temperature was mapped, using a color coded calibration of temperature for each image set [5-7].

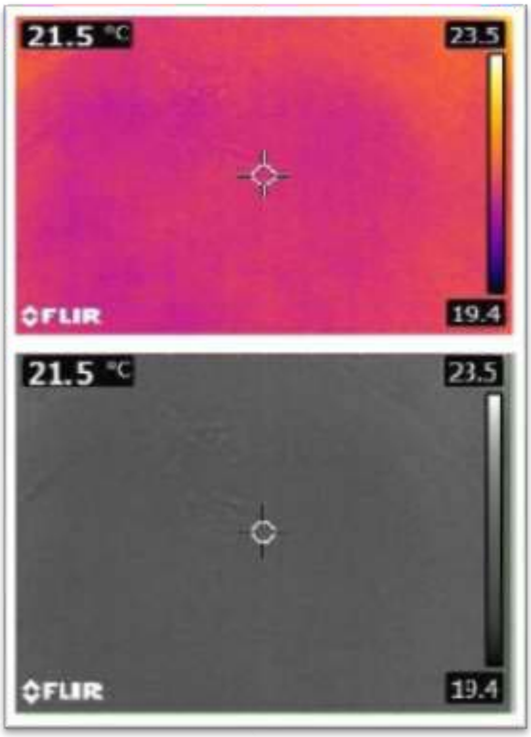

Figure 1. RGB (above) and grayscale (below) thermal camera images of Ca-S cement.

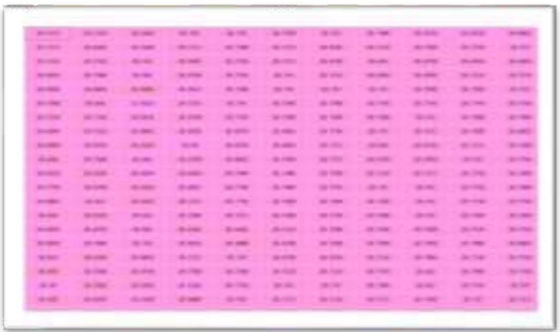

Figure 2. Temperature map of ROI [20,10] of a 1S:9F sample.

III. RESULTS AND DISCUSSION

The setting time of Ca-S cements were determined by the Vicat apparatus. The 1:12 Ca-S cements were set at 620±62 sec. and 1:9 Ca-S cements were set at 1130±65 sec.

Thermal camera tests, indicated that Ca-S cement setting involved an exothermic reaction, where sample temperature increased losing mass as water. However, the results indicate that loss of mass may correlate but is not a reliable and descriptive indicator. After the Ca-S cements were set, temperature began to decrease. Using image segmentation techniques, the exothermic nature of this reaction was confirmed with the observed temperature increment spreading from the inner to the outer boundaries of the cement media. It was seen that the temperature profile of Ca-S cements increased homogenously during the exothermic reaction.

All of the 1S:9F samples displayed an increase in temperature upto about 18.5 min., indicating experimental accuracy (Fig. 3). The 1S:12F samples displayed an initial increase in temperature up to 10.5 min., followed by a fall (Fig. 3). The decrease in setting time correlating with the findings of the Vicat Test indicated that the end of reaction coincided with the point where the temperature dropped. The image processing results similarly indicated that at the end of the reaction, heat transfer on the outer surface of the petri dish stops and the Ca-S cement begins to transfer heat to the environment. The averages and standard deviation values demonstrated consistency between the recorded surface temperatures, temperature maps and the calibrated mean temperatures.

The histograms of both groups of samples displayed presence of different temperature regions appearing on the cement surface during the reaction progress. In the 1S:12F samples, with the decrease in temperature, higher numbers of bins of different temperature regions appeared (Figs. 4,5), which can be due to the cooling effect of ambient temperature appearing in the images.

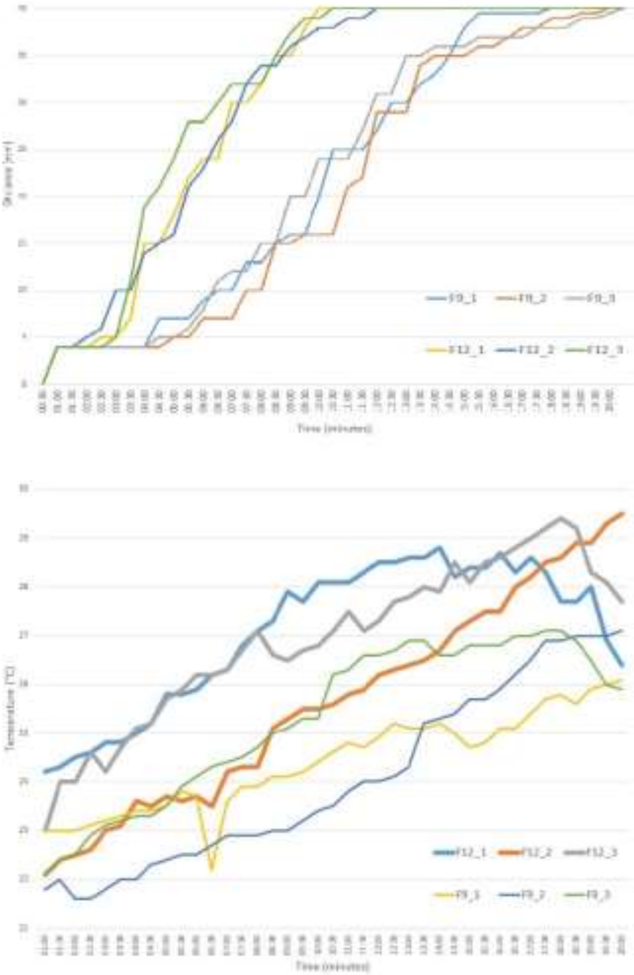

Figure 3. Vicat Test (above) and thermal camera (below) results for 1S:9F and 1S:12F samples.

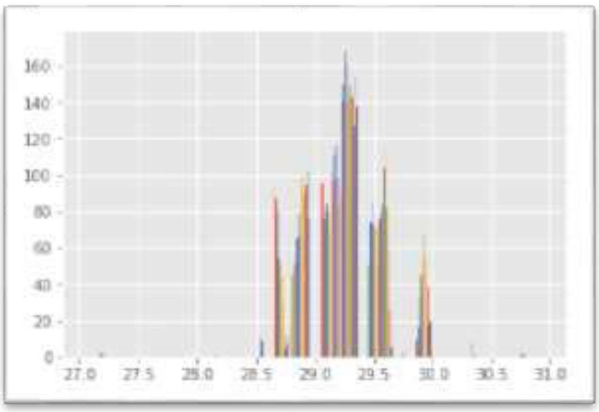

Figure 4. Histogram plot of 1S:9F sample (80. Image).

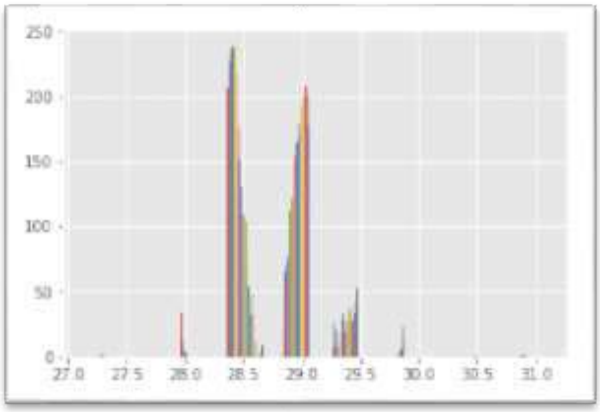

Figure 5. Histogram plot of 1S:12F sample (80. Image).

IV. CONCLUSION

In this study alternative methods involving image processing techniques for determining the setting time for Ca-S cements were proposed. The setting time for fast and slow drying Ca-S cements was determined by the Vicat Test and compared with the results obtained by alternative methods using temperature and mass change. The results indicate that setting time may be described using image processing techniques on images obtained by a thermal camera, while loss of mass may correlate but is not a reliable and descriptive indicator. The image processing results indicate that the reaction process is exothermic and that the temperature rise spreads from the inner to the outer boundaries of cement surface. In order to increase accuracy and the reliability in future studies, sample size should be increased.

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