IMPLEMENTATION OF INFRARED THERMOGRAPHY ON DEFECTS MONITORING DURING CAVITATION EROSION OF MULLITE CERAMIC

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Cavitation erosion of mullite samples was monitored using vibratory cavitation set up with stationary sample. The level of degradation of the sample was monitored using weight loss and image analysis. Thermal imaging analysis was focused on determination of temperature line profile and histogram of temperature distribution at the end of the experiment. The results of image analysis were compared with infrared thermography results.

Key words: mullite, cavitation erosion, defects, image analysis, thermal imaging

Introduction

Mullite belongs to a group of a high temperature ceramic material with good mechanical strength and excellent thermal shock properties. Typical applications include, but are not limited to, coatings including thermal barrier coatings, thermocouple applications, furnace muffle tubes, kiln rollers, sight tubes, rods and kiln furniture [1—3].

Cavitation erosion of engineering materials was investigated and results were related to the different types of steel, coatings, as well as the engineering ceramic materials [4—9]. Cavitation erosion is a phenomenon, which can be observed where fluids, which are transported with some velocity, are in contact with engineering material. In this study, image analysis is applied for characterization of the damage level during cavitation erosion testing, using determination of the damaged and non-damaged surface.

Among non-destructive techniques (NDT), the infrared thermography (IRT) is the only diagnostic technology allowing the operator to instantly visualize and verify thermal performance [10—14]. Active thermography represents a non-destructive technique, which is based on observing temperature differences with an infrared camera after a thermal excitation. It is divided into lock-in thermography LT, pulse thermography PT, pulsed phase thermography PPT [10—14]. In this paper, this approach was used for temperature line profile and histogram of temperature distribution determination at the end of experiment.

Experiments

Materials

Mullite is a good, low cost refractory ceramic with a nominal composition of $3Al_2O_3 \cdot 2SiO_2$. In this paper mullite powder was used for sample preparation. Samples were pressed and sintered at 1200°C for 3 hours. XRD and SEM of the obtained samples are given in Fig. 1. XRD confirmed presence of mullite and α corundum (Fig.1.a.) The structure after sintering was with small grains, high density and some porosity (Fig. 1, *b*).

Cavitation erosion testing

Cavitation erosion testing was performed according the procedure described by ASTM G32 standard [4—9]. The ultrasonic vibratory cavitation set up was used. Stationary specimen method was applied according to the ASTM G32 standard. The usual characteristics for the frequency and peak-to-peak displacement

amplitude of the horn were used, as well as characteristics of liquid [4—9]. In order to obtain the erosion curve, the weight loss measurements were performed after each exposure interval. The weight loss was recorded every 10 min for a test period of 80 min. Weight losses of the tested specimens were measured using the analytical balance with the accuracy of ±0.1 mg.

a) b)

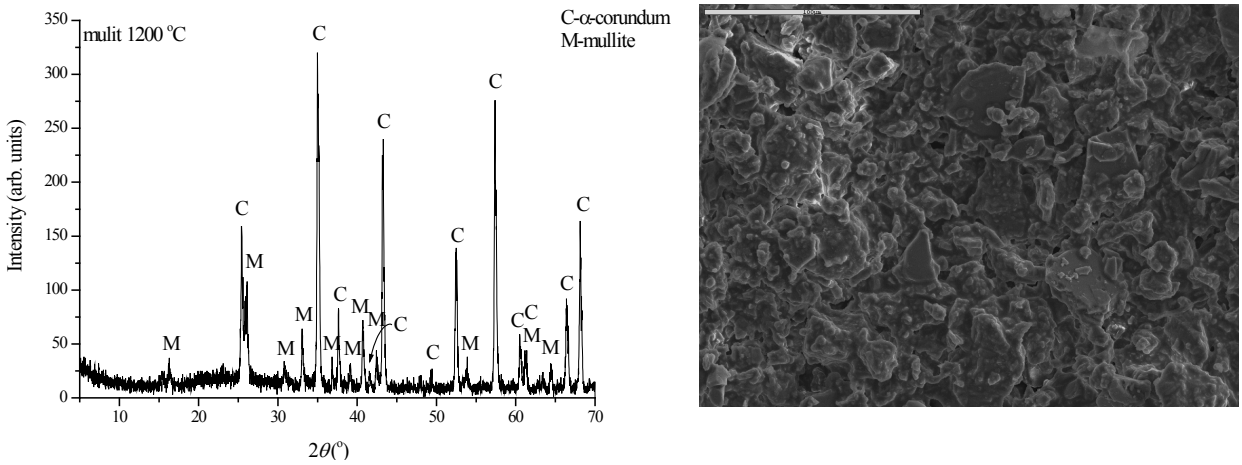

Fig. 1. XRD (*a*) and SEM (*b*) of the mullite sample

Results and discussion

Image analysis results

During testing, as it could be seen from the obtained results (Fig. 2, 3), the degradation occurred, and its level was increasing during the time of experiment (Fig. 3). The results of the image analysis applied for monitoring the level of degradation are given in Fig. 3, where the time of exposure is related to the level of degradation, which is over 25% after 80 minutes.

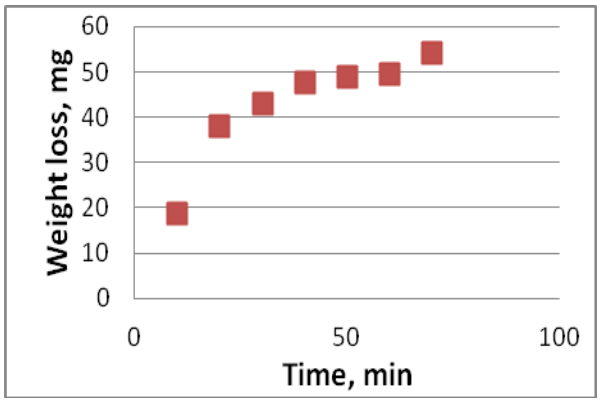

Fig. 2. Weight loss

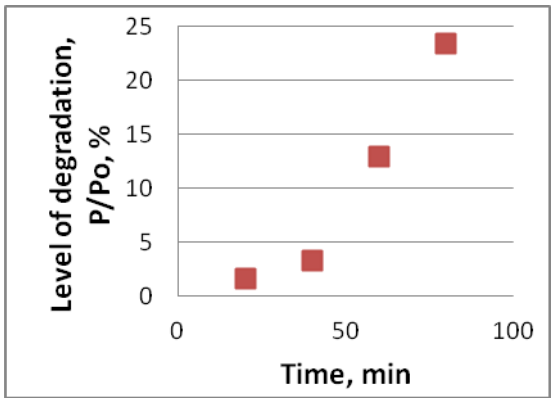

Fig. 3. Level of degradation during cavitation erosion testing

Thermal imaging

Mullite samples after 80 minutes of cavitation erosion testing were heated by two IR lamps for 90 seconds and then cooled for 630 seconds. This mode was applied as in previous experiments [14]. The thermal changes at the sample surfaces, which allow discovering defect zones, can be noticed after only 15 seconds of cooling. The results of IR-heating and observed changes of temperature are presented in Fig. 4.

Based on the obtained results presented in Fig. 4, *a* and *b*, the temperature profile of the sample indicates formation of degradation area. However, these results are not too detailed, so the number of pits, as

well as their dimensions, could not be measured. Similar can be said about the results given in Fig. 4, *c* and *d*, which confirm that temperature changes are caused by cavitation erosion, but these results could not be related to the dimensions of the pits.

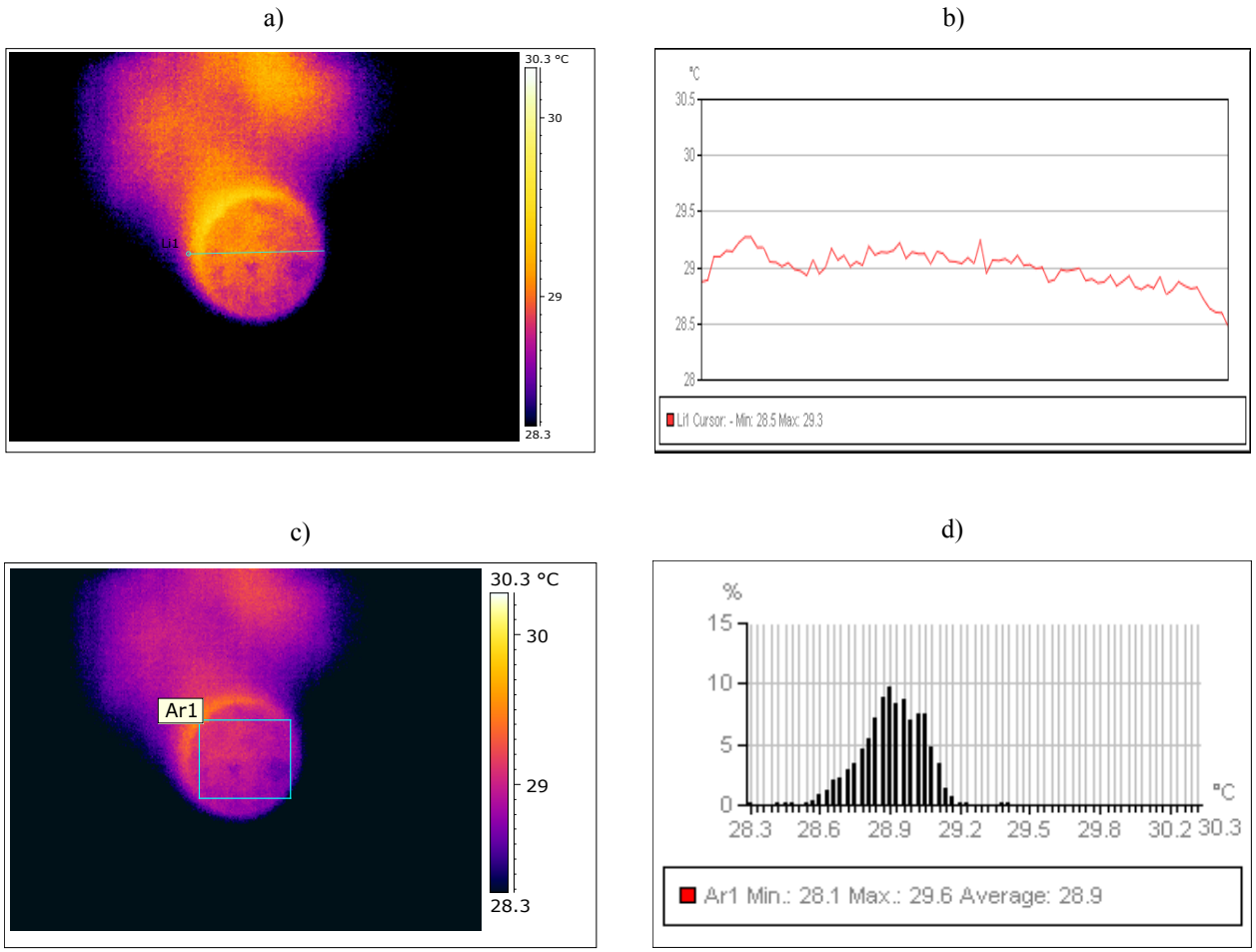

Fig. 4. Thermal imaging:
a, c — thermographic images; *b* — temperature line profile;
d — temperature distribution histogram

Conclusion

Thermal vision imaging was used for temperature distribution and histogram of the samples at the end of the testing period (80 minutes). The obtained results showed that image analysis could be a useful tool for determining the level of degradation, while thermal vision imaging could be used for degradation detection. First approach is cheaper and requires a common camera, unlike the thermal vision, where good and reliable results are strongly dependent on the resolution of the camera, which makes the procedure much more expensive. However, when the temperature is higher than the room temperature, thermal imaging could be very useful.

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Реалізація інфрачервоної термографії для моніторингу дефектів впродовж кавітаційної ерозії мулітової кераміки

Проведено моніторинг кавітаційної ерозії зразків муліту за допомогою вібраційної кавітаційної установки з використанням стаціонарного зразку. Ступінь деградації зразку було контрольовано за допомогою втрати ваги і аналізу зображень. Тепловізійний аналіз було зосереджено на визначенні профілю лінії температури і гістограми розподілу температури в кінці експерименту. Результати аналізу зображення були зіставлені з результатами інфрачервоної термографії.

Ключові слова: муліт, кавітаційна ерозія, дефекти, аналіз зображення, тепловізія.

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