Available online at www.sciencedirect.com

ScienceDirect

Procedia Structural Integrity 8 (2018) 618–627

Structural Integrity Procedia

www.elsevier.com/locate/procedia

AIAS 2017 International Conference on Stress Analysis, AIAS 2017, 6-9 September 2017, Pisa, Italy

Thermo-structural analysis of components in ceramic material

Gianluca Chiappini[a,*], Marco Sasso[a], Tiziano Bellezze[b], Dario Amodio[a]

[a]Dipartimento DIISM, Facoltà di Ingegneria, Università Politecnica delle Marche, Via Brecce Bianche, 12, 60100 Ancona, Italy
bDipartimento SIMAU, Facoltà di Ingegneria, Università Politecnica delle Marche, Via Brecce Bianche, 12, 60100 Ancona, Italy.

Abstract

The aim of this paper is the systematic study of thermo-structural behavior of ceramic components, in particular, mixtures of refractory materials with high thermal and mechanical performance. Using 3-point bending tests, the elastic modulus, ultimate stress and elongation was obtained; measured values, also thanks to the use of DIC optical technology, was correlated with the different thickness and specific weight values of the specimens used. In order to characterize the thermal behavior, thermal conductivity and specific heat were measured. The experimentally determined average values of such thermomechanical properties have been used in FEM thermo-mechanical models, developed using target geometries with shapes and sizes typical of manufactured ceramic products. In order to evaluate the goodness and the correctness of the developed models, some specimens having the the same shape of the target geometries used in FEM models have been tested at different load conditions and constraints.

Peer-review under responsibility of the Scientific Committee of AIAS 2017 International Conference on Stress Analysis

Keywords: ceramic material, thermo-structural analysis, three-point bending test, DIC

1. Introduction

The ceramic components industry has developed refractory mixtures with high thermal and mechanical performance; these mixtures are used to produce valuable components that are typically used in tables and professional

* Corresponding author. Tel.: +39 071 2204440; fax: +39 071 2204801.
E-mail address: g.chiappini@univpm.it

2452-3216
Peer-review under responsibility of the Scientific Committee of AIAS 2017 International Conference on Stress Analysis
10.1016/j.prostr.2017.12.061

countertops (e.g. for analysis laboratories). However, their high performance permits more extensive use of these mixtures: considering both the non-negligible value of the realized products and the increasing production demand, it emerges the need to develop systematic procedures for verifying and predicting the behavior of the ceramic products, when they are subjected to several different exercise loads, especially thermal ones. It is common for this class of components to fracture due to intense mechanical stresses, which are induced by differential thermal expansion between adjacent areas of the component. This may be due, for example, to uneven heating/cooling, and may be accentuated or mitigated by the presence of holes, thickness variations and geometric complexities in general.

The aim of this paper is therefore to determine the mechanical and thermal characteristics of these materials through experimental tests carried out on different types of specimens. In addition, the aim is to develop numerical models that will allow to study and optimize the behavior of ceramic objects.

Of course, in the study the stochastic nature of physical quantities of interest was considered, due to both the craftsmanship of the manufacturing processes and the inherent variability of the physical characteristics of the mixtures (due to supply and environmental conditions).

The work is divided into several phases that can be summarized as follows:

1) Determination of mechanical and thermal properties
2) FEM Modeling of interest objects
3) Numerical / experimental verification and correlation

Nomenclature

E	Young's Modulus
σ_r	Ultimate stress
ε	Strain
L	Length of the specimen
b	Width of the specimen
t	Thickness of the specimen
C_p	specific heat
α	thermal expansion coefficient
λ	thermal conductivity

2. Methods

2.1. Three-point Bending Test

In order to determine the mechanical characteristics of the ceramic material, three-point bending tests of various thickness specimens, and various types of superficial glaze, was performed. During tests, carried out with an electro-mechanical testing machine Zwick® Z050, load are measured by a 5 kN load cell whereas displacement and deformation are measured using the DIC optical technique (Fig. 1a).