

Quasi-static compression behavior of nickel oxide, nickel oxide: zirconia, nickel:zirconia and nickel foams

Papiya Biswas, Pandu Ramavath, Chandhana Muraleedharan Nair, Madireddy Buchi Suresh, Nakula Ravi, Roy Johnson*

International Advanced Research Centre for Powder Metallurgy and New materials (ARCI), Hyderabad 500005, India

ARTICLE INFO

Article history:

Received 9 November 2015

Received in revised form

17 March 2016

Accepted 17 March 2016

Available online 10 April 2016

Keywords:

Mechanical properties

Fracture

Composites

Strength

ABSTRACT

An effective material for use in shock mitigation should spread the deflection of the shock wave over a longer period of time and should minimize the force felt by the object under impact. Ductile or brittle cellular materials are currently gaining importance due to their unique high energy absorption characteristics. Reticulated cellular foam structures of nickel oxide (NiO) and nickel oxide:zirconia (NiO:YSZ 60:40 percentage by wt.) were fabricated by polymeric sponge replication process. These foams are reduced under hydrogen atmosphere to produce metallic nickel (Ni) and nickel:zirconia (Ni:YSZ) cermet foams, respectively. X-ray diffraction studies on the struts confirmed the corresponding phase formation. Further, the volume fraction of the solid in foam is estimated through image analysis. All the foams are subjected to uni-axial compression and the stress–strain curves were recorded. A comparative evaluation of progressive deformation behavior at room temperature was also carried out. Stress–strain curve of the nickel foam shows distinctly three regimes under compression, a deformation regime showing a linear dependence in the strain with stress. This is followed by a second region showing a plateau corresponding to the energy absorption resulting from the permanent plastic deformation while retaining the integrity and finally densification region through the wall collapse resulting in the maximum compressive strength. Stress–strain curves of all other foams such as NiO, NiO:YSZ and Ni:YSZ has demonstrated a similar fracture behavior under compression which caused not only by unstable crack propagation originating from a single crack, but also by merging of many cracks leading to the formation of the crushed zone. Compressive strength is found to be a strong function of solid fraction supporting the load and percentage porosity of NiO foams. Estimation of relative energy absorption has exhibited higher energy absorption irrespective of the material of construction at higher strain rates.

© 2016 Elsevier Ltd and Techna Group S.r.l. All rights reserved.

1. Introduction

Light weight ductile or brittle cellular materials which exhibit high energy absorption characteristics are a unique class of materials for shock attenuation applications [1–4]. Cellular materials are generally composites composed of a solid phase with interconnected porosity as a secondary phase [5,6]. These are generally formed in two major configurations, such as honeycombs and foams. Honeycombs exhibit two-dimensional array of cells and foams possess three-dimensional polyhedral cells. A cellular material can be generally characterized based on their relative density, constituent material, cell topology and cell geometry. Further, the adaptability to tailor the structures based on above variables can derive a combination of properties especially high stiffness-to-

weight ratio with thermal, acoustic and energy absorbing properties [7–11]. Unlike the solids, the base material in the cellular form on tailoring properly, has the ability to absorb the energy by various mechanisms such as bending, buckling or by fracture. Energy absorption is a measure of the ability of the material to transform the kinetic energy. The cellular material, to be safe under impact, the kinetic energy transfer should be less than the maximum energy absorption capacity of the material and on exceeding the energy absorption capacity limit, the material becomes sacrificial.

Quasi-static compression test generally provide the understanding on the most of the mechanical properties of the cellular material under crushing load. Metallic foams generally absorb energy by deformation through plastic flow and ductile fracture; however, ceramic foams absorb by fracture due to their inherent brittleness. Further, composites or cermets may exhibit a mixed behavior. In the present study, reticulated foam structures of nickel oxide (NiO), an oxide ceramic and nickel oxide:zirconia ceramic

* Corresponding author.

E-mail address: royjohnson@arci.res.in (R. Johnson).

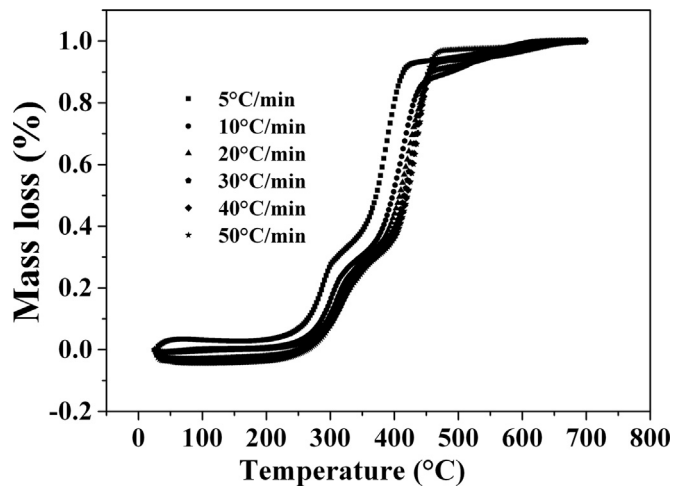


Fig. 1. TG/DSC curves of PUF.

matrix composite (NiO:YSZ 60:40 percentage by wt.) were fabricated through the polymeric sponge replication process. These samples are reduced under hydrogen to convert the foams into nickel (Ni) metal foam and nickel:zirconia (Ni:YSZ) cermet foam.

Table 1
Cellular properties of the foams.

Sample	Cell diameter (mm)	Strut thickness (mm)	PPI	Pitch (mm)	Void fraction (%)	Density (g/cc)
PUF	2.031	0.486	10	2.49	92.99	–
NiO	1.72	0.510	12	2.23	86.04	4.58
NiO-YSZ	1.26	0.460	12	1.72	85.17	4.57
Ni-YSZ	1.83	0.490	12	2.32	81.11	3.41
Ni	1.31	0.650	12	1.96	85.81	7.85

All the foams were characterized by XRD and subjected to compression to evaluate the behavior under crushing load. The stress-strain curves were correlated with progressive failure events and fractography of struts, to evolve a probable crushing mechanism and further energy absorbed under the quasi-static compression was estimated. NiO foam samples were also sintered at different sintering temperatures and foams with varying porosities and pore density of 23 and 35 PPI in addition to 12 PPI were also fabricated and compression tested. Compression strength is found to be a strong function of percentage porosity and pore density as revealed by the test results.

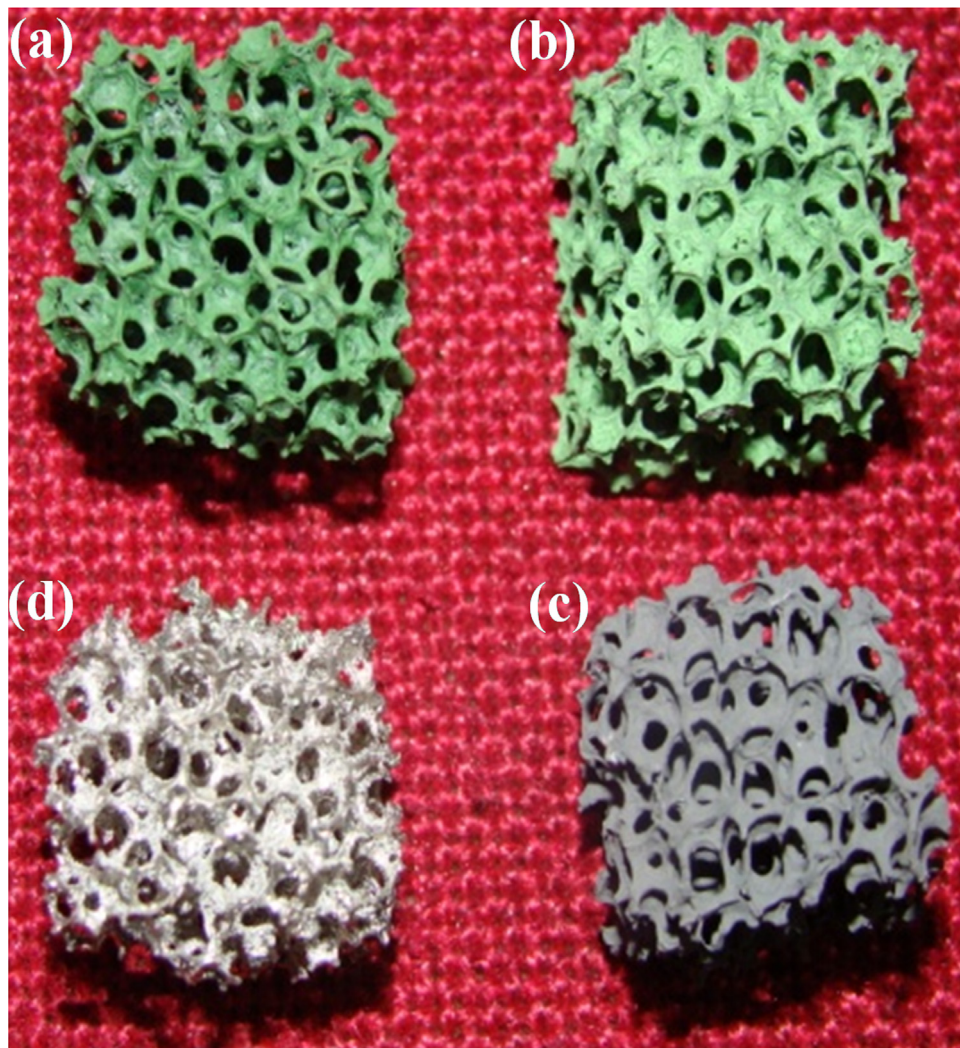


Fig. 2. Photographs showing (a) nickel oxide, (b) nickel oxide:zirconia, (c) nickel: zirconia and (d) nickel foams.

Download English Version:

<https://daneshyari.com/en/article/1458593>

Download Persian Version:

<https://daneshyari.com/article/1458593>

[Daneshyari.com](https://daneshyari.com)