

Modelling the Viscoelasticity of Porous Ceramics

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Abstract. Porous ceramics are considered as candidate materials for well-established and emerging engineering applications because of the unique combination of their attractive properties. Therefore, considerable research has been conducted to produce porous ceramics with different pore size distribution, by employing different processing strategies. Most common porous ceramics exhibit viscoelastic behaviour in nature or during the process of porous ceramics production. In the theory of linear viscoelasticity, creep and relaxation functions are the important delay kernels in the stress-strain relations. A creep function has been proposed in modelling the porous ceramics rheology. The corresponding form of the relaxation function is derived using the interconversion formula.

Keywords: porous ceramics, viscoelastic, creep function, relaxation, porosity, interconversion formula

1. Introduction

Porous ceramics are considered as candidate materials for well-established and emerging engineering applications because of the unique combination of their attractive properties [1,2]. For example, macroporous ceramics with pore sizes from 400 nm to 4 mm and porosity within the range 20%–97% have been produced for a number of well-established and emerging applications, such as molten metal filtration, catalysis, refractory insulation, and hot gas filtration [2]. These applications take advantage of the unique combination of their attractive properties, such as low density, controlled permeability, high thermal shock resistance, high specific strength and chemical stability at high temperatures into solid ceramics [2]. Considerable research has been conducted to produce porous ceramics with different pore size distribution, by employing different processing strategies, in terms of fabrication of porous ceramics, such as replica, sacrificial template, direct foaming and reaction technique [1,3,4]. Each processing strategy influences on the microstructure and the mechanical derived porous ceramics. Most common porous ceramics exhibit viscoelastic behaviour in nature or during the process of porous ceramics production. For example, the synthesis of heat-resistant ceramic foams by using viscoelastic nature of silicone resins [1], or during direct foaming method, which produce stiff viscoelastic foams with unprecedented long term stability [2]. The aim of this paper is to propose a certain creep function in modelling the porous ceramics rheology, in which the corresponding form of the relaxation function is derived using the Interconversion formula [6,7]. The motivation follows from the mechanical properties of porous ceramics, where compressive strength and elastic modulus decreased exponentially as the porosity increased [5]. Based on the given information on the creep function and relaxation function, this will hopefully give better understanding on how to predict better estimation of the compressive strength, elastic modulus and the processing methodology, for future production of good quality porous ceramics components.

2. Creep Function of the Power Law form $J(t)=At^a$

The Creep function is the delay kernel of the integral in the fundamental equation for the strain due to the variable applied stress, and the viscoelastic modulus is readily related to the creep function via their Laplace transforms. The creep function and the relaxation modulus are also readily related to the relaxation function, which is the delay kernel of the integral in the fundamental equation for the stress corresponding to the

variable strain. It was found that the creep function was found to obey power law behaviour [8] for variable applied stress.

2.1 Interconversion Equation

The Interconversion Equation of linear viscoelasticity [6,7]

$$\int_0^t G(t-\tau)J(\tau)d\tau = \int_0^t G(\tau)J(t-\tau)d\tau = t$$

Normally subject to $G(0)J(0) = G(\infty)J(\infty) = 1$, relates the creep function $J(t)$ to the relaxation function $G(t)$. Thus the relaxation function may be estimated from the more readily obtained experimental determination of the creep function.

2.2 The Form of Relaxation Function Corresponding to Creep Function

We have shown [7] that in the case of the experimental result

$$J(t) = At^\alpha$$

for constants A and $\alpha > -1$, the corresponding relaxation function is $G(t)$ is

$$G(t) = \frac{1}{A\Gamma(1+\alpha)\Gamma(1-\alpha)} t^{-\alpha}$$

where Γ denotes the familiar Gamma function.

3. Experimental Methods

As an illustration for a creep function found to obey power law behaviour in porous materials processing, Ludwigson and others [8] produced composite samples of 40% by volume Silicon Carbides (SiC) in Indium-Tin (InSn) matrix by fabrication method, with the aim of achieving a high value of the product of stiffness and viscoelastic damping, without excess density, and found a similar dependence for an arbitrary creep function, i.e. $J(t)=At^\alpha$, a power law, which can fitted over a particular value of time t .

4. Expression form of Relaxation Function G(t)

One can find the relaxation function $G(t)$ over a particular time t , with values obtained from [8], in which the parameter A is found to be approximately 7.50 GPa. If one choose α to be 0.3 respectively, as popular power exponent, used to study porous materials especially in cells [9], then one finally obtain the expression form of relaxation function $G(t)=kt^{-\alpha}$, $k=1/(7.5) \Gamma(1.3) \Gamma(0.7)$, a real number.

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6. References

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