

INFLUENCE OF POROSITY ON VELOCITY OF ULTRASOUND AND
 ELASTIC MODULI IN SINTERED NICKEL

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The marked effects of porosity on the elasticity and strength of ceramic materials have been the subject of several experimental and theoretical investigations [1-4].

A. Nagarajan [5] has done ultrasonic study of elasticity-porosity relationship in polycrystalline alumina.

S. Stoimenov and Z. Stojanov [6] suggested velocity-porosity and elasticity-porosity relationship in sintered copper.

The initial porosity for the four nickel's powder samples obtained by pressing was: 0.217, 0.193, 0.189 and 0.185. These samples were sintered on various isothermic temperatures (873-1273K), in H₂ atmosphere for one hour. Due to different temperatures their porosity had changed.

The values of the total porosity were determined by relation

$$P = 1 - \rho_p / \rho_t \quad (1)$$

ρ_p is experimental obtained values of density in examined samples and ρ_t is following density in compacted materials.

Table I

ρ (ρ_t)/m ³)	P	V_L (m/s)	V_T (m/s)	$G \times 10^{10}$ (N/m ²)	$K \times 10^{11}$ (N/m ²)	$E \times 10^{11}$ (N/m ²)
8900	0.000	5992	3112	8.619	2.046	2.267
8600	0.034	5613	2968	7.505	1.699	1.979
8520	0.043	5622	2898	7.155	1.739	1.888
8500	0.050	5539	2883	7.065	1.666	1.857
8410	0.055	5401	2802	6.602	1.573	1.738
8360	0.061	5335	2830	6.695	1.478	1.746
8260	0.072	5105	2720	6.111	1.338	1.591
8130	0.086	4955	2647	5.696	1.236	1.481
8030	0.098	4944	2602	5.436	1.238	1.423
7950	0.107	4853	2553	5.182	1.181	1.362
7780	0.126	4705	2440	4.632	1.105	1.219
7250	0.185	4088	2147	3.342	0.766	0.875
7220	0.189	4023	2122	3.251	0.735	0.850
7180	0.193	3901	2101	3.169	0.670	0.821
6970	0.217	3815	2028	2.867	0.632	0.747

After each thermal treatment at room temperature voluminal characteristics were controled. At the same temperature velocities of ultrasonic waves were measured and elastic moduli were detrmind.

The velocities of ultrasonic waves were measured by PULSE ECHO OVERLAP METHOD, proposed by Papadakis[7].

The velocities of ultrasonic waves were measured at 10MHz, for longitudinal, and 6MHz for transversal waves for all samples.

Using the theory of elasticity [8], shear modulus (G), bulk modulus (K) and Young's modulus were determined by following relations:

$$G = \rho V_t^2 \quad (2)$$

$$K = \rho (V_L^2 - \frac{4}{3}V_t^2) \quad (3)$$

$$E = \rho V_t^2 (3V_L^2 - 4V_t^2) / (V_L^2 - V_t^2) \quad (4)$$

On the table I the experimentally determined values of the: density, porosity, velocities and elastic moduli are given.

By means of a linear least squares fitting analysis the following relationship between velocity of ultrasonic waves and porosity was obtained:

$$V_{L(m/s)} = 5992(1 - 1.761P) \quad (5)$$

$$V_{L(m/s)} = 3112(1 - 1.267P) \quad (6)$$

On the base of the relations (5) and (6), the general relationship between velocity and porosity is the following

$$V = V_k(1 - kP) \quad (7)$$

where with the V_k the value of velocity in unporous materials is marked. The value of the constant k depends on examined materials' properties.

The relation (7) give possibility of porosity evaluations by means of measured velocity.

Figures 1 and 2 represent measured longitudinal (V_L) and

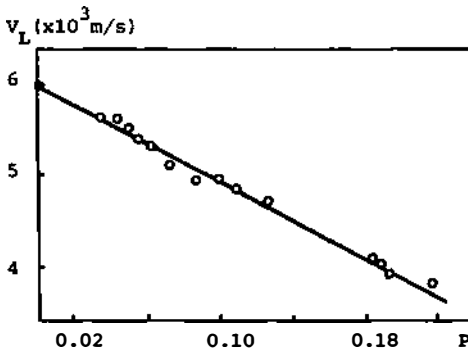


Fig. 1

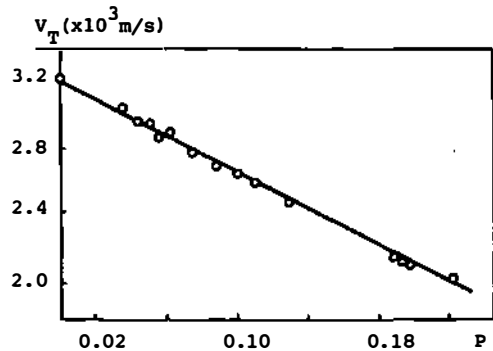


Fig. 2

transversal (V_T) velocities as a function of total porosity (P).

By using a least squares method, quadratic functions of the total porosity were fitted to the experimental determined moduli.

For Young's modulus (E), bulk's modulus (K) and shear modulus (G), one can use the following relations:

$$E_{(10^{11} \text{N/m}^2)} = 2.267 - 9.940P + 14.591P^2 \quad (8)$$

$$K_{(10^{11} \text{N/m}^2)} = 2.046 - 9.511P + 13.126P^2 \quad (9)$$

$$G_{(10^{10} \text{N/m}^2)} = 8.619 - 35.786P + 38.485P^2 \quad (10)$$

Relations (8), (9) and (10) are graphically presented in figures 3, 4 and 5. It may be noticed that these relations are no linears.

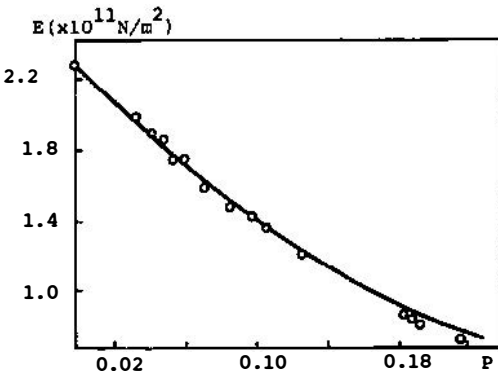


Fig. 3

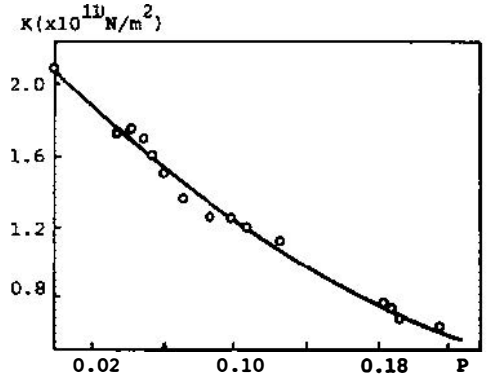


Fig. 4

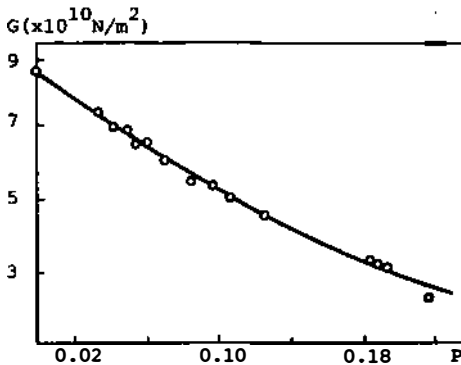


Fig. 5

As a result of the last three relations, the relationship between any elastic modulus (M) and porosity (P), can be described as the following generalized line:

$$M = M_k - k_1 P + k_2 P^2 \quad (11)$$

M_k presents the value of the corresponding elastic modulus (E , K or G) in unporous material and values of the constants k_1 and k_2 are determined with porous materials properties.

The relations (7) and (11) obtained for examined nickel are of the same type as relations obtained by examined alumina [5] and copper [6].

It is of great importance that we can determine the values of velocity by use of the relation type (7), and of elastic moduli by relation type (11), if we know the values of porosity. On the base of the experimental obtained values of longitudinal (V_L) or transversal (V_T) velocities of ultrasons it is possible to obtain values of porosity, by graphical method by using the fig. 1 or fig. 2 respectively. By the thus obtained values of porosity one can determine elastic moduli (E , K and G) from fig. 3, 4 and 5.

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