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RESEARCH ARTICLE

EVALUATION OF STIFFNESS CONSTANT C_{11} AND MEYER INDEX OF BIOMATERIALS PROSOPIS JULIFLORA AND CASUARINA EQUISETIFOLIA

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ABSTRACT

Vickers and Knoop micro hardness tests were carried out on the pressed pellet form of Prosopis juliflora and Casuarina equisetifolia biomaterials subjected to a load range of 25–100g. Vickers (*H*v*)* micro hardness for the above loads was found to be in the range of 29–57 kg/mm^2 and 107-136 kg/mm^2, for P.juliflora and C.equisetifolia respectively. Knoop (H_k*)* micro hardness number was found to be in the range 22–51 kg/mm^2 and 82-127kg/mm^2, for P.juliflora and C.equisetifolia respectively. Vickersmicrohardness number (H_v*)* and Knoop micro hardness number (H_k) was found to increase withincreasing load for both materials. Yield strength(σ_v) was calculated using H_v. Meyer's index number (*n*) calculated from H_v shows that the materials belonging to the soft material category. Using Wooster's empirical relation, the elastic stiffness constant (C_{11}*)* was calculated from Vickers hardnessvalues. Young's modulus was calculated using Knoop hardness values. Our study reveals that C.equisetifolia having high modulus of elasticity than P.juliflora.

INTRODUCTION

Theimportance of hardness for crystals has been discussed by various researchers (Nimisha *et al*, 1997; Pandya *et al.*, 1999; Subhadra *et al.*,2000; Rao *et al.*,2002; Sangita *et al.*, 2005) for various applications, since mechanical strength is oneof the important properties of any device materials representedby its hardness. Measurement of hardness provides useful information aboutthe mechanical properties such as elastic constants (Wooster, 1953) and yield strength (Westbrook,1958), etc. The hardnessis estimated from the ratio of the load applied on indenterto the area of the impression left on the specimen. BothVickers and Knoop hardness tests were carried out on the biomaterials Prosopis juliflora and Casuarina equisetifolia. Meyer's index *(n)*was found to be >1·6 showing soft materialcharacteristics.Using Wooster's empirical relation, the elastic stiffnessconstant (C_{11}*)* was calculated from Vickers hardness values.For calculating Young's modulus, Knoop indentations were used.

MATERIALS AND METHODS

One to two kilograms of P.juliflora and C.equisetifolia was collected from the plantation. They were oven dried at 70°C during 24h. The samples were then grinded into powder.

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The sample prepared with P.juliflora and C.equisetifolia powder by pressing them in pellet form with 1.3 mm diameter and 1.12mm thickness at a constant pressure of 5 metric tons. The pressed pellet of P.juliflora was subjected to the mechanical studies.

Micro hardness

Mechanical characterization of P.juliflora and C.equisetifoliabiomaterials was doneby Vickers and Knoop micro hardness studies at room temperature. Pellet with flat and smooth surface was chosen for static indentation tests was mounted on the clamping devices to the base of the microscope controlled by XY travel stage of dimensions 50 × 50 mm (2' × 2'). Now, the selected face was indented gently by loads varying from 25-100 g for a dwell period of 10s using both Vickers diamond pyramid indenter and Knoop indenter attached to an incident ray research microscope (Mututoyo MH 112, Japan). Vickers indented impressions were approximately square in shape. Length of the two diagonals was measured by a calibrated micrometer attached to the eyepiece of the microscope after unloading and the average was found out. For a particular load, at least five well defined indentations were considered and the average of all the diagonals (*d)* was considered. H_v was calculated using the standard formula (Pal and Kar 2005):

$H_v = 1{\cdot}8544\ P/d^2$(1)

Where*P* is the applied load in kg, *d* is in mm and H_v is in kg/mm^2. The Yield strength was calculated using H_v. The

Knoop indented impressions were approximately rhombohedral in shape. Average diagonal length (*d*) was considered for the calculation of Knoop micro hardness number (H_k) using the relation (Pal and Kar 2005):

$H_k = 14{\cdot}229P/d^2$ (2)

where P is the applied load in kg, d is in mm and H_k is in kg/mm^2. Crack initiation and fragmentation become significant beyond 100g of applied load. So hardness test could not be carried out above this load. The stiffness constant C_{11} was calculated from Wooster's empirical relation (Wooster 1953),

$C_{11} = H_v^{7/4}$ (3)

RESULTS AND DISCUSSION

Vickers micro hardness

Figure 1 shows variation of H_v as a function of applied load ranging from 25-100 g for P.juliflora and C.equisetifolia. It is very clear from the figure that H_v increases with increase in load. Meyer's index number was calculated from Meyer's law (as discussed by Jagannathan *et. al.*, 2007), which relates the load and indentation diagonal length as

$P = kd^n$,

$\log P = \log k + n \log d$ (4)

where k is the material constant and 'n' the Meyer's index. The above relation (4) indicates that H_v should increase with P, if n >2 and decrease with P when n <2. This is well satisfied as shown by Figure 1.

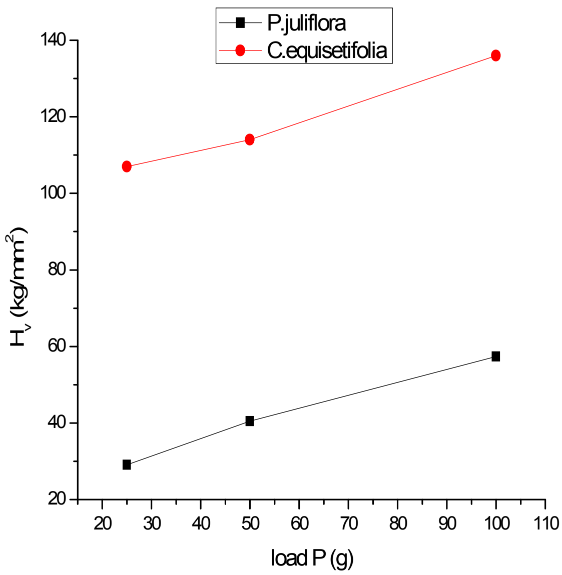

Figure 1.Variation of Vickers micro hardness number *H*v with load

In order to find the value of 'n', a graph is plotted for log P against log d (Figure 2, Figure 3), which gives a straight line (after least square fitting). From the slope line, Meyer's index number 'n' was calculated and was found to be 3.7, 2.34 for P.juliflora and C.equisetifolia respectively.

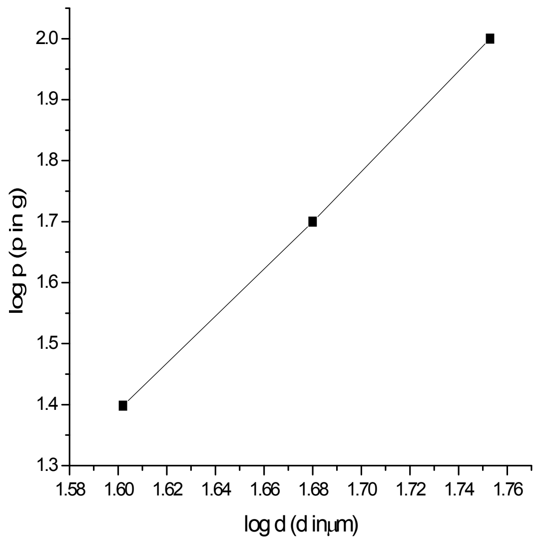

Figure 2.Graph between log *P* vs log *d* of P.juliflora

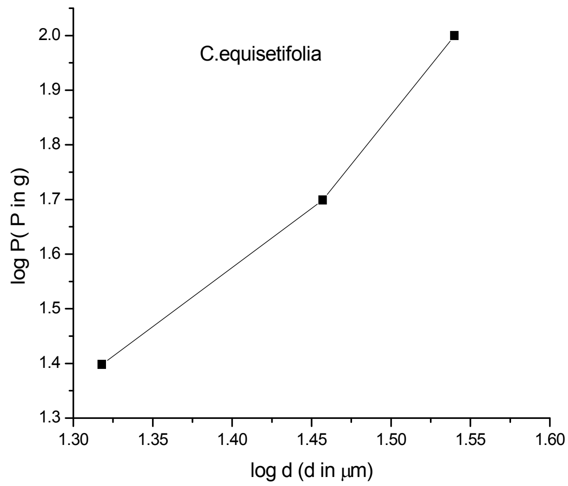

Figure 3.Graph between log *P* vs log *d* of C.equisetifolia

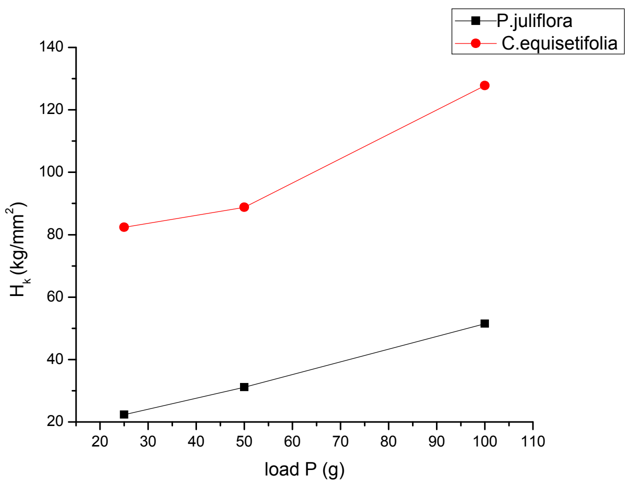

Figure 4.Variation of Knoops micro hardness number *H*k with load

Table 1.Variation of elastic Stiffness Constant (C_{11}), Young's modulus (*E*)and Yield strength with load.

S.No	Load (g)	Stiffness Constant C_{11} (x 10^{14} Pa)		Young's modulus *E* (Gpa)		Yield Strength σ_v (MPa)	
		P.juliflora	C.equisetifolia	P.juliflora	C.equisetifolia	P.juliflora	C.equisetifolia
1	25	3.57	34.81	1.32	5.17	9.7	35
2	50	6.37	39.00	1.8	5.06	13.5	38
3	100	11.74	53.11	2.8	7.50	19.13	45.3

According to Hanneman (1941), the values of *n* were 1–1·6 for hard materials and more than 1·6 for soft ones. Thus, both biomaterials are belonged to soft material category. Elastic stiffness constant (C_{11}) was calculated by Wooster's (1953) empirical relation. Stiffness constant for different loads calculated from Vickers hardness values are shown in Table 1. A graph (Figure 4) was plotted for Knoop hardness (H_k) against load (*P*). From the graph, it was found that as the load increases, the Knoop micro hardness number also increases, which is due to the reverse indentation size effect (Sangwal2009). From Knoop micro hardness measurements, Young'smodulus (*E*) of the crystal was calculated using the relation (Pal and Kar 2005),

$E = 0{\cdot}45\ H_k/[0{\cdot}1406 - b/a]$(5)

whereH_k is Knoop micro hardness value at a particular load, and *b* and *a* are the shorter and longer Knoop indentation diagonals, respectively. The calculated Young's modulus for various loads is shown in Table 1.

Conclusions

Vickers and Knoops micro hardness for P.juliflora and C.equisetifolia was calculated by the application of load in the range 25–100 g. Meyer index suggests that C.equisetifolia is harder than P.juliflora. The value of C_{11} gives the idea of toughness of bonding between neighboring atoms. Here, the value of C_{11} indicates that the binding forces between the ions in C.equisetifolia are stronger than the P.juliflora. Since modulus of elasticity for C.equisetifolia is high we can conclude that C.equisetifolia is more flexible than P.juliflora.

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