A NOTE ON THE RELATIONSHIP BETWEEN POROSITY DATA AND INTERVESSEL PIT DIMENSION[1]

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ABSTRACT

Data on porosity, charring temperature, mercury intrusion, pit dimensions, and density of black cherry char are summarized and examined statistically in an attempt to elucidate relationships between measured parameters. Pit dimensions were not related to porosity, but were related to real density. Porosity is found to be related to mercury intrusion, real density and temperature.

Key words: Char, porosity, intrusion, real density, apparent density, pits.

INTRODUCTION

The structure of pits is one of the major avenues of material transport in wood. Knowledge of pit dimensions coupled with information on porosity obtained using a mercury porosimeter should provide insight into the efficacy of pits in the flow of materials in char porosity. The porosity of black cherry char has been investigated using a mercury porosimeter (Blankenhorn et al. 1978), as has the relationship between pit dimensions and charring temperatures (Elder et al. 1979). This note reports the relationships between porosity, charring temperature, density, and the planar dimensions of intervessel pits on the same black cherry char used in the previously reported studies.

METHODS AND MATERIALS

The material used in this study was the same as that reported in Blankenhorn et al. (1978) and Elder et al. (1979). Black cherry (*Prunus serotina* Ehrh.) specimens were carbonized at a rate of 3 C/min in flowing nitrogen to selected target temperatures (Fig. 1), held at that temperature for two hours, then cooled to ambient at 2 C/min. SEM samples were split, coated with 200–300 Å of gold palladium, and randomly selected intervessel pit apertures were measured on

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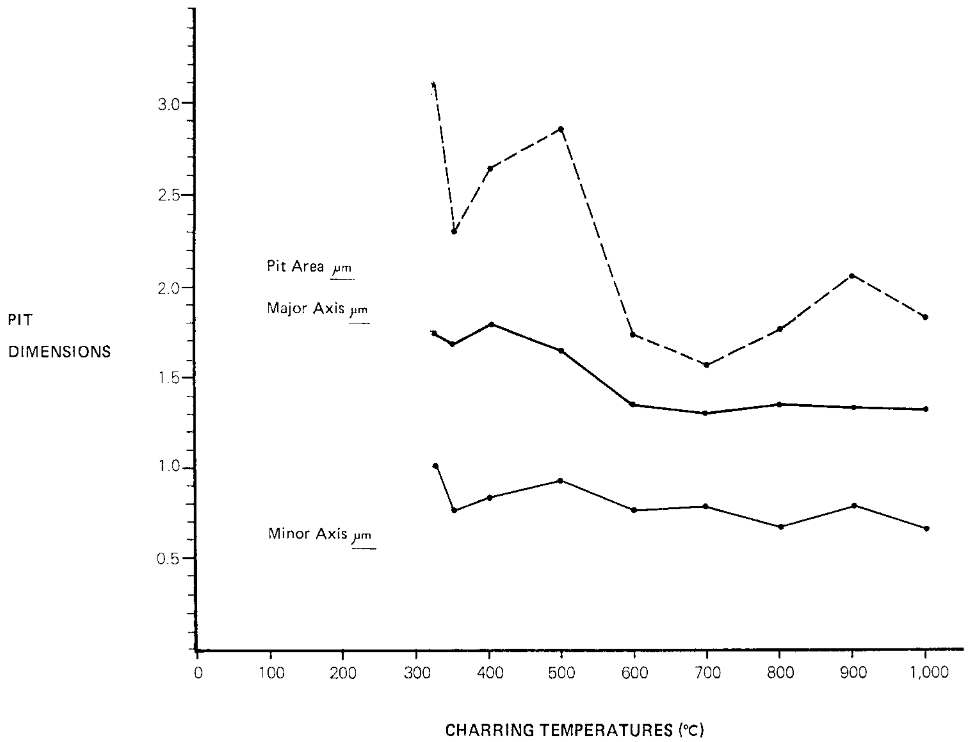

FIG. 1. Changes in pit dimensions with temperature.

SEM micrographs (Elder et al. 1979). Porosimetry data were developed using mercury intrusion porosimeters with either a 30,000 or 60,000 psig capacity (Blankenhorn et al. 1978). The data were analyzed by analysis of variance and regression techniques.

RESULTS AND DISCUSSION

The temperature of the char is highly related to the pit dimensions as shown in Table 1. Significant differences of pit dimensions occur among charring temperatures (Elder et al. 1979). The final temperature of the charring process and intervessel segment pit dimensions in the char are not linearly related over the entire range of charring temperatures investigated (Fig. 1). When the temperatures separated at the 600 C inflection point are compared (Table 2), two events are noteworthy: 1) within the lower temperature range (320–500 C) the minor axis versus temperature and the area versus temperature are significantly different ($\alpha = 0.05$), and 2) the regression of the major axis versus the higher temperatures approaches a zero slope. The area measured in both of these temperature ranges is influenced by these two events with the pits approaching an elliptical shape. The major axis, assumed to be parallel to the fibrils, is relatively stable. The cell wall apparently coalesces in the plane of the minor axis. This may explain Christner's (1972) observation of refractiveness of cellulose charred above 600 C.

Real density determined by porosimetry is the specimen mass divided by real

TABLE 1. *Summary of regression relationships.**

Significant ($P > 0.05$) Linear Relationships	Pr > F	r^2 or R^2
Major Axis = 4.102 − 2.078 Real Density	0.0431	0.681
Pit Area = 10.931 − 6.907 Real Density	0.0362	0.706
Pit Area = 5.087 − 2.142 Intrusion	0.0337	0.822
Porosity = 32.998 + 20.429 Intrusion	0.0038	0.901
Porosity = 17.381 + 18.820 Intrusion + 14.417 Real Density	0.0004	0.995
Porosity = 15.210 − 0.002 Temp + 18.099 Intrustion + 17.930 Real Density	0.0017	0.999
Anova	PR > F	
Temp vs. Minor Axis	0.0001	
Temp vs. Major Axis	0.0001	
Temp vs. Pit Area	0.0001	

* Real density (g/cc); Intrusion (cc/g); Temperature (°C); Minor axis (mm); Major axis (mm) and Pit area (mm²).

volume of the specimen as determined by subtracting the volume displaced in mercury at maximum penetration pressures from the apparent volume (Blankenhorn et al. 1978). Correlations between real density and pit dimensions increase respectively as the minor, major, and area dimensions are considered. Real volume is a function of the penetrability of mercury as described by Blankenhorn et al. (1978). The larger the pit dimension measurement, the greater the predictability for density as determined by real volume and conversely, the less the effect of the cell interstices, demonstrated by pits, on porosity. If cell interstices significantly entered into the porosity data, the event would be recorded at the higher pressures. Since this did not occur, we can assume that at the maximum pressures the interstices are not major pathways for mercury nor other materials.

TABLE 2. *Analysis of variance and correlation values for pit dimensions and porosity data of black cherry char.*

	F value	PR > F	r^2
Temp vs. Minor Axis	17.39	0.0001	
Temp vs. Major Axis	7.95	0.0001	
Temp vs. Pit Area	9.43	0.0001	
320–500 Temp vs. Minor	20.29	0.0001	0.1715
320–500 Temp vs. Major	1.34	0.2506	0.013448
320–500 Temp vs. Area	5.50	0.0211	0.053122
600–1,000 Temp vs. Minor	3.05	0.0836	0.0302
600–1,000 Temp vs. Major	0.002	0.9663	0.000018
600–1,000 Temp vs. Area	1.84	0.1784	0.018403
Pit Minor Axis vs. R Dens	5.50	0.0790	0.578785
Pit Major Axis vs. R Dens	8.55	0.0431	0.681192
Pit Area vs. R Dens	9.62	0.0362	0.705279
Pit Minor Axis vs. Intrusion	5.34	0.1040	0.640143
Pit Major Axis vs. Intrusion	5.89	0.0936	0.652416
Pit Area vs. Intrusion	13.87	0.0337	0.822126
Pit Minor Axis vs. Porosity	5.10	0.1092	0.529405
Pit Major Axis vs. Porosity	4.68	0.1192	0.609414
Pit Area vs. Porosity	8.23	0.0641	0.732894

Intrusion measures the volume of mercury in the sample over the oven-dry mass of the sample and its units are the reciprocal of real density. Intrusion, however, had a significant relationship ($P > 0.05$) with the major axis. Both have relatively high r^2 values. The minor axis of pits had no effect on the penetrability of, nor were they apparently a detriment to, the passage of mercury through the intervessel pits.

There is no relationship between apparent density, the oven-dry mass divided by apparent volume, and pit measurements. The size of the pits does not restrict the movement of mercury into the structure even though the pit dimensions decrease in size with increasing charring temperature.

Porosity is a percentage of the total pore volume divided by the sample apparent volume determined by submersion in mercury at atmospheric pressure. The total pore volume is the difference between the apparent volume and the real volume determined by mercury intrusion under pressure and as such is a relationship of volumes. Intrusion is a measure of volume of mercury per unit mass of char. The intrusion of mercury into the fine structure of the char as measured through porosimetry into interstices is not significant to the intervessel pit dimensions. Siau (1971) suggested that transport phenomenon in wood may be controlled by the smallest openings. Pit dimensions do not enter into stepwise regressions (Table 1). The initial regression model was porosity against temperature, intrusion, major pit axis, minor pit axis, pit area, apparent density, and real density. Porosity was found to be significantly related to mercury intrusion with an r^2 of 0.9012. The addition of real density to the model resulted in a significant relationship with R^2 of 0.9946. The equation with temperature, mercury intrusion, and real density was also significantly related to porosity with an R^2 of 0.9989.

It should be noted that while the three term equation adequately explains the behavior of the material, the addition of other terms does not markedly increase the regression coefficient over the simple regression of porosity vs. intrusion even where pit dimensions are included in a multiple regression model. These pits are undoubtedly a portion of the void volume; however, they must represent such a small part of the total void volume that there is no relation between them and the total void volume of the char. Pit dimensions might not affect porosity to any significant extent. However there are some significant relationships between pit dimensions and the variables of temperature, real density, and mercury intrusion (Table 2).

SUMMARY AND CONCLUSION

The efforts reported herein are part of a continuing effort to relate anatomical changes to physical parameters upon subjection of wood to elevated temperatures. It has been found that pit dimensions do not influence porosity, but are related to real density. Porosity, as would be expected, is quite dependent on the degree of mercury intrusion, but it is also related to real density in the regression evaluation.

In an attempt to further understand the charring process, and as an aid in the characterization of carbons, additional anatomical studies may be of interest in determining the role of other structures in relation to porosity of carbonized material.

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