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Thermochimica Acta 287 (1996) 293–298

thermochimica acta

Dilatometry analysis of Moroccan acacia wood under a nitrogen atmosphere

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Received 9 February 1996; accepted 22 April 1996

Abstract

The pyrolysis of a Moroccan wood species (*Acacia mearncii*) under an inert atmosphere has been studied by thermogravimetry and dilatometry. The wood undergoes contraction depending on the direction measurement relative to that of the annual growth rings. The contraction is greater in the direction perpendicular to the annual rings compared with the parallel direction.

Keywords: Annual rings; Dilatometry; Wood

1. Introduction

Thermal analytical methods have been widely used in the study of biomass thermochemical conversion processes. Biomass, which represents a renewable energy, consists primarily of plant cells differentiated into characteristic tissues and organs. Generally, during thermal treatment the solid products undergo changes. Dimensional variations may be more or less pronounced when the studied solid undergoes degradation. These dimensional variations can be measured by dilatometry.

The thermal decomposition of wood is a complex process [1–4] which indicates that degradation occurs in discrete stages of moisture evolution, hemicellulose decomposition, cellulose decomposition and lignin decomposition [1,5–7]. Information on changes in wood microstructure and elemental composition during pyrolysis has also been presented [5].

Dilatometry (DL) analysis of raw materials during thermal investigation also allows determination of the temperature ranges where the main degradation steps take place.

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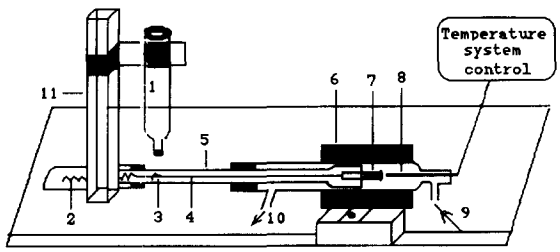
PII S0040-6031(96)03021-3



1- Field-glass; 2- Spring; 3- Brander; 4- Kanthal wire; 5- Silica tube; 6- Oven; 7- Sample; 8- Thermocouple; 9- Gas inlet; 10- Gas outlet; 11- Support.

Fig. 1. Experimental apparatus.

2. Experimental

In order to obtain information about the dimensional changes occurring during pyrolysis with uniform heating rates in a nitrogen environment, the thermal evolution of *Acacia mearncii* wood was studied using a dilatometer made in our Laboratory (Fig. 1).

The dilatometer functions as follows: the sample is held in position by kantal wire at the extremity of a thin quartz tube. The sample remains in this position due to a spring that links the other extremity of the tube to the kantal wire. The movement of the free extremity of the spring enables the change in dimension of the sample to be monitored.

Allowance for the expansion of the kantal wire was made by carrying out measurements on two samples of different lengths. The difference in the length measurements corresponding to the absolute expansion is equivalent to the difference in the length of the sample before and after the turn.

The dilatometry study was carried out on parallelepipedic forms having a constant area of 9.61 mm^2 and a height ranging from 2.65 to 6.55 mm. These samples were introduced into a dilatometer under a nitrogen flow rate of 15 $cm^3 min^{-1}$ and a heating rate of 15°C min^{-1}.

The prepared samples had parallelepipedic shapes with four faces perpendicular to the annual rings and two faces parallel to the annual rings. These geometrical forms were obtained by abrasion at room temperature and atmospheric pressure.

All the experiments were carried out with two types of samples: parallelepipedic shape with the height perpendicular to the annual rings; parallelepipedic shape with the height parallel to the annual rings.

3. Results

The results obtained from this study, which follow the perpendicular and then the parallel direction to the annual growth rings, show that *Acacia mearncii* wood exhibits a contraction with temperature.

Fig. 2 illustrates these results where each curve shows, the absolute variation ($-\Delta L$) of the sample dimension perpendicular and parallel to the annual rings for the samples.

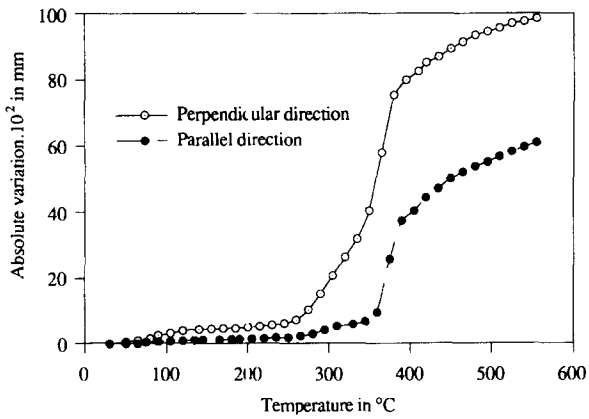


Fig. 2. Absolute variation of sample dimension in the perpendicular and parallel directions.

We notice that the absolute variation ($-\Delta L$) is more important in the perpendicular direction than in the parallel one.

The process of weight loss in the thermal decomposition (pyrolysis) of *Acacia mearncii* in nitrogen has been studied thermogravimetrically by means of dynamic experiments carried out under various conditions [8]. The differential thermogravimetric (DTG) curve for the pyrolysis of *Acacia mearncii* (Fig. 3) shows three different regions corresponding to:

(i) decomposition of hemicellulose;
(ii) decomposition of cellulose;
(iii) decomposition of lignin.

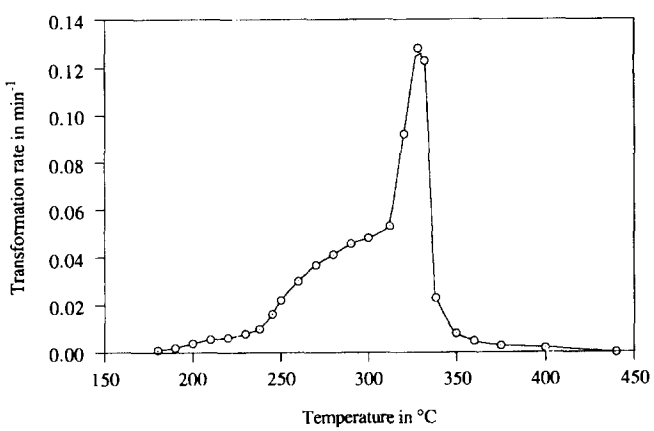


Fig. 3. DTG pyrolysis curve of acacia wood.

If we present data for the changes per unit length $\Delta L/\Delta L_0$ (where L_0 is the initial length of the sample) and the conversion fraction (Fig. 4), the variation in sample dimension is greater in the perpendicular direction than in the parallel one. The following remarks can be made regarding the experimental results.

(i) In the temperature range from 20 to 160°C, we notice a low contraction corresponding to dehydration which indicates a slight loss of mass. After this stage, the thermogravimetric curves (TG) show a horizontal region up to approximately 180°C. After this stationary phase, the curve ascends, corresponding to a more significant loss of mass. This weight loss is related to degradation of the organic matter as volatile products.

(ii) Between 180 and 300°C, a slight shrinkage is observed, due to decomposition of hemicellulose and cellulose.

(iii) In the temperature range from 300 to 400°C, a pronounced shrinking on the dilatometric curve appears which indicates lignin decomposition.

(iv) Secondary reactions and the desorption of organic matter, fixed by charcoal, take place after 400°C. These phenomena are shown by the slowing down in the shrinking of the residual solid and the weight loss.

Comparison of TG with ΔL curves shows correlations between weight and dimension changes. Thus, loss of moisture is accompanied by a low dilatometric change; however, decomposition of organic matter is accompanied by shrinkage of sample in both directions.

We notice that the more important shrinking phenomenon observed corresponds to lignin degradation, which is more important in the perpendicular direction than in the parallel one. But in a global way, the perpendicular contraction (43%) is twice as important in the parallel direction (22.6%).

The values of the linear contraction coefficient (α_L) were determined from the expression of the first derivative $d(\Delta L/L_o)/dT$, i.e. the slope at a given temperature of the plot of dilatometric curve ($-\Delta L/L_0 = f(T)$).

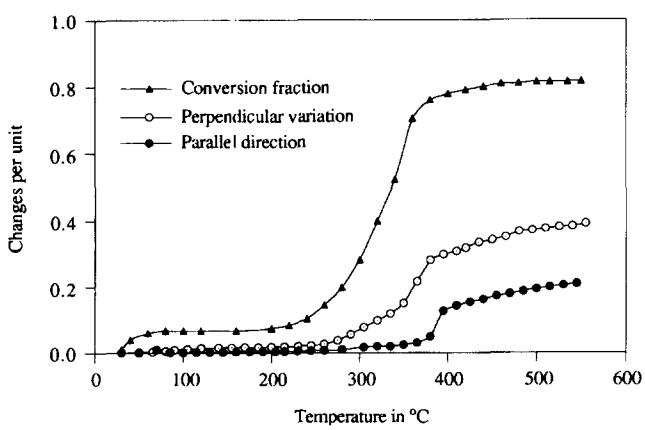


Fig. 4. TG and ΔL curves versus temperature.

Table 1
Temperature regions of the decomposition of each component

Temperature range/°C	Heating rate 15°C min^{-1}/Component
180–240	Hemicellulose
240–310	Cellulose
310–400	Lignin

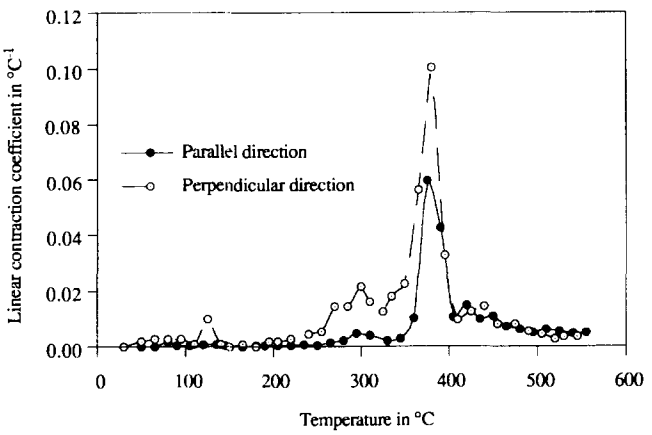


Fig. 5. Perpendicular and parallel variation of linear contraction coefficient with temperature.

Fig. 5 shows the first derivative $d(\Delta L/L_0)$ of the linear contraction of the sample direction with respect to temperature . We notice that following the perpendicular direction, the linear contraction coefficients are more important and the maximium contractions for each orientation occur at the same temperature (380°C) at which the lignin decomposition is also maximum.

4. Conclusion

We have shown that the degradation of different components does not lead to the same type of contraction. The more important relates to lignin degradation. In a general way, the maximum loss of weight is due to higher contraction in the same temperature range for the same kind of components.

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