Study of Growth stress and Resistance of the cracking of the wood of Grown Eucalypti and Quercus Ilex

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***Abstract*— The liberation of the growth stress during the cutting down and the cutting into sections prevents the use of increased wood of Eucalyptus and the Quercus ilex as wood of work. The operations of first transformation modify the mechanical balance and provoke afterward fissuring in the form of cracks in end of grapes. The importance of the fissuring, which in connection with the mean value of growths stresses indicators (GSI), also depends on both intrinsic properties of the wood, the failure stress has a tensile and the fracture toughness in the distribution of crack. Measures of the growth stress indicator (GSI) were made on two broad-leaved trees of different sorts, three trees of grown Eucalyptus and three trees of the Quercus ilex by means of the method of the only hole. Essays of drive were made on specimens of massive wooden drive, to study the mechanical behavior during load. To estimate the fracture toughness by the method of compliance, essays of break in mode I were made on massive wooden specimens DCB.**

The study of the growth stress indicator (GSI), in the suburb of trees, showed, generally speaking, that both essences behave differently. Indeed, for the grown eucalypti sort with fast growth, 75 % of the values of the moderate GSI are lower than 90 µm. This value was only 31 µm for the Quercus ilex sort with slow growth. The grown Eucalypti presents a strong nervousness translated by strong values of GSI associated generally to the wooden presence of reaction (wood of tension). The massive wood presents a fragile behavior with failure stress of drive and a fracture toughness of the Quercus ilex more raised than that of grown Eucalyptus. These two essences have a similar average rigidity.

Keywords— Grown Eucalypti; Quercus ilex; growth stress; failure stress; Bing; fracture toughness)

I. INTRODUCTION

The eucalyptus and the Quercus ilex have a major socioeconomic function in Morocco. Indeed, except for the use of the wood of eucalyptus in the industry of the paper mass and the perches, and that of the Quercus ilex for the skeleton and the manufacturing of sleeves of agricultural tools and various utilitarian objects, these two essences supply only with some wood of heating and with some charcoal [1]. The part of the eucalyptus and the wooden Quercus ilex of work remains limited enough because of the liberation of the growth stresses during cutting down and of the cutting into sections (development of cracks and deformations).

The study of the growth stresses, which arouses the interest of several research teams, evolves towards a global approach of the mechanics of the tree in connection with botanists, anatomists and psychologists [2]. The accent is put on the study of the longitudinal deformations, which intervene in the reorientations of stalks and the distribution of the wood of reaction. Longitudinal deformations (α_L) and tangentielles (α_T) are blocked, which provokes the creation of a field of stress, for every new coat of cells. By using the law of elasticated behavior with a state of stress plane (σ_L, σ_T), for the last formed coat, we write the following:

$$\begin{pmatrix} \sigma_T{}^p \\ \sigma_L{}^p \end{pmatrix} = -\frac{1}{1-\nu_{TL}\nu_{LT}} \begin{pmatrix} E_T & \nu_{LT}E_T \\ \nu_{TL}E_L & E_L \end{pmatrix} \begin{pmatrix} \alpha_T \\ \alpha_L \end{pmatrix}$$

Where $\sigma_L{}^p$, $\sigma_T{}^p$ represent the state of stress in suburb

Studies tried to draw the parallel between a modelling of the stress in suburb of the trees and the deformations due to the liberation of these same stresses. The study is realized on eucalyptus; the mode of sawing remains simple because it consists in cutting partially a grape in four districts, and in measuring the space between four districts [3].

II. MATERIALS AND METHOD

A. Plant material

The plant material is constituted by three trees of grown Eucalypti and three trees of Quercus ilex of Moroccan origin. The selected trees have one diameter included between 30 and 60 cm. They are straight and present few defects. In the table1, we put back the measures of some dendrometric characteristics such as the total height h_t, the circumference $C_{1,30}$ in 1,30 m of the ground, the age and the thickness of the bark E_e

Table 1. Dendrometric characteristics of the trees on feet.

Species	N° trees	h_t (m)	$C_{1.30}$ (cm)	E_e (cm)	Age (ans)
Grown eucalypti	1	32,51	135	0,82	≈ 45
	2	37,03	117	1,01	
	3	40,15	135	0,84	
Quercus ilex	1	15,35	130	1,06	≈ 85
	2	17,05	116	1,46	
	3	17,24	161	1,14	

B. Measure of the deformations of maturation on the surface of the tree on feet

The To estimate the rigidity of trees on feet by means of a parameter named growth stress of indicators (GSI), the method of the only hole was used. This method consists in measuring the relative immediate movement of two points fixed to a distant D = 45 mm on the surface peeled by the tree (Fig.1). Both headlands are aligned according to the direction of fibers. A size allows positioning the headland of the comparator with digital reading MITUTOYO with a precision of 3 µm and a capacity of 12 mm movement. The leaky hole is equidistant with both headlands. We proceeded to a progressive drilling with a diameter of 20 mm. During this drilling, the cut fibers loosen. This relaxation results from the modification of the field of stress provoked by the drilling and can thus be connected with the deformations blocked in the tree. The relative movement δ is so recorded, as soon as the comparator indicates a stable value, while the operation of drilling continues. We noticed that this stabilization takes place for a depth of hole varying between 10 mm and 20 mm. The movement integrates the tension into the surface of the removed wood, and the characteristics of the wood staying on foot. The calculations led by R.R. Archer and H. Bailleres [4] connect the variation of distance δ with the longitudinal residual deformation by: $\varepsilon_L = -\Psi_{Th}\delta$: In the case of the standard broad-leaved trees, the value of the factor ψ_{Th} is 12,3 µdef / µm.

The results obtained by the growth stress of indicator GSI are going to be presented in terms of movement, that is to say from the value directly read on the sensor

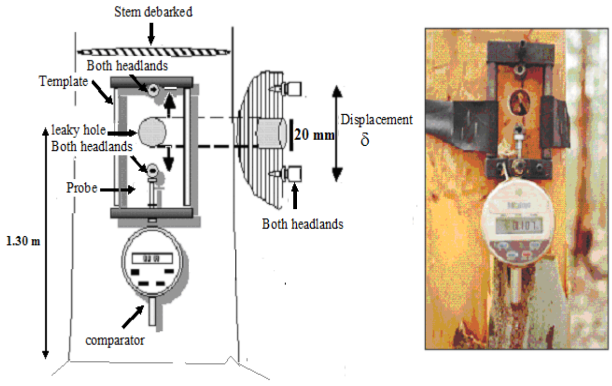

Fig.1. Measure of the growth stress of indicator GSI by the method of the only hole

On a crown situated at a height of 1,30 m of the ground with a step of 45, we made eight measures on every tree. They are tracked down by: 1, 2, 3, ……….8 by turning clockwise Fig.2:

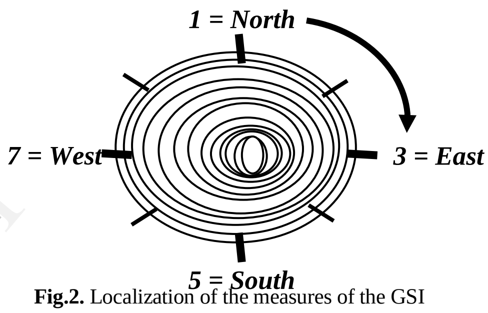

Fig.2. Localization of the measures of the GSI

C. Essays of mechanical characterization of grown Eucalypti and of the Quercus ilex

On billions of grown Eucalypti and Quercus ilex, we made a sawing in contact (parallel sawing). The drying is realized by means of a partly industrialized classic traditional hairdryer Cathild to determine the rate of humidity. Once boards were stabilized in a humidity of about 12,5 %, we proceeded to the preparation of specimens

D. Tensile resistance and in the distribution of crack

A series of 20 specimens of drive, following the French Standard NF 51-022 and another series of 15 specimens DCB were made in the laboratory of the Physical essays and Mechanics of the wood in Rabat.

We made essays of drive on massive wooden test tubes (Fig. 3), and essays of break in mode I on massive wooden specimens DCB (Fig.4).

The essays were realized with a machine of drive of capacity 300 KN piloted by computer. The speed of movement of the crossbar was fixed to 0.5 mm/mn for the tensile specimens of drive and to 1 mm/mn for DCB specimens.

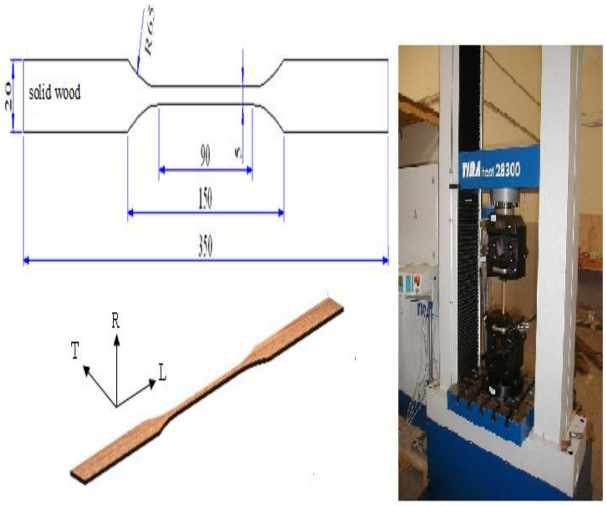

Fig.3. Tensile specimens and Principle of the testing

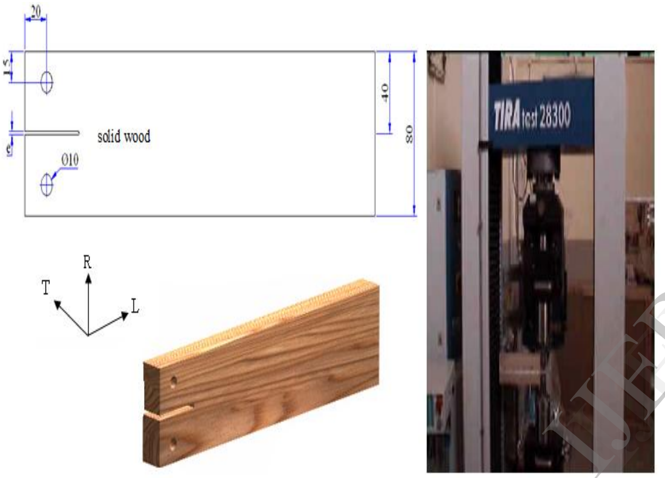

Fig.4. DCB specimens and Principle of the testing

E. *Module of elasticity of Timoshenko and Bernouilli*

A series of 30 test tubes of dimensions 20 * 20 * 360 mm3 (RTL) was made, according to the standard NF B 51-008 and serve for determining the mechanical properties by the vibratory method called BING. This method is based on the analysis of the appropriate frequencies of echo of a test tube in answer to an impulse request applied to one of its extremities [5]. The test tube is placed on two elasticated bracelets of weak rigidity and a shock at the level of one of the extremities allows seeking the modes of vibration of this specimens. The passed on signal is registered in the other extremity by means of a microphone. This signal is treated by a procedure FFT (Fast Fourier Transform). From the geometrical dimensions, from the mass in a humidity about 12 %, first modes of vibration of the test tube and by means of the theory of Timoshenko on the floating beams (Appendix), we estimated the modules of elasticity

Fig.5. Protocol of BING test.

III. RESULTS

A. *Growth stress of Indicators GSI*

In the table 2, we put back the mean values, the maximum and the minimum of the measures of GSI, as well as the corresponding coefficients of variation for three trees of both studied sorts.

Table 2. Experimental Results of the measures of GSI of three 3 trees of grown Eucalypti and three trees of Quercus ilex.

	Trees	GSI_{max} (µm)	GSI_{min} (µm)	GSI_{moy} (µm)	CV %	Age (ans)
Grown eucalypti	1	84	47	65	21	45
	2	152	81	104	17	
	3	105	34	75	23	
	average	-	-	81	-	
Quercus ilex	1	51	0	24	22	85
	2	60	12	26	25	
	3	23	4	13	19	
	average	-	-	21	-	

The table 2 shows that the grown eucalypti have a strong average value of GSI, about 81µm compared with the Quercus ilex 21µm. This difference can be explained by the effect of the age which is about 45 years for the grown eucalypti and 85 years old for the Quercus ilex and by the effect of the speed of fast growth for the Eucalyptus increased and slow for the Quercus ilex. The polar representation of the GSI (Fig. 6), for both essences, allows localizing the strong values of the GSI. Indeed, for the grown eucalypti, the strongest value of the GSI is registered for the tree 2 tilted towards the direction 2, as for the Quercus ilex, the strongest value of the GSI is observed on the tree 2 tilted to the direction 1. For these trees, we note weak values of the GSI on the opposite side.

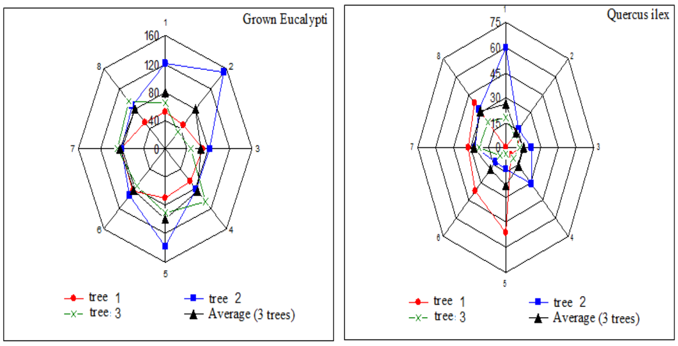

Fig. 6. Polar representation of the GSI for three trees and the average

As comparison of these two broad-leaved trees, the observation of the curves of distribution accumulated by the frequencies of GSI (Fig. 7) allows at any time to appear a net difference between these two essences. Indeed, at the level of the values of the GSI, 75 % of grown eucalypti have deformations lower than 90 µm. This value is 31 µm for the Quercus ilex.

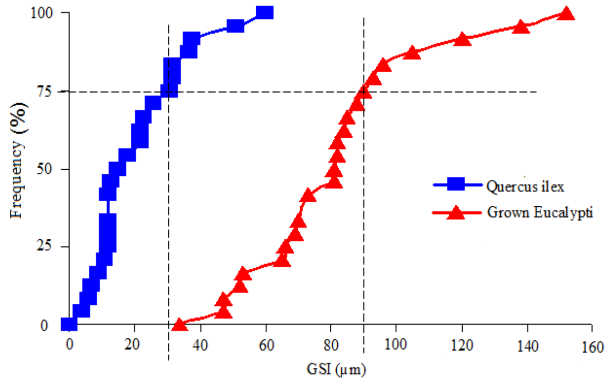

Fig. 7. Distribution accumulated by the GSI of Grown Eucalypti and by Quercus ilex

The angular representation of the experimental values of the GSI, centred around the maximal value, reflects the intensity of the stress of growths inferred during the maturation, for three trees of grown eucalypti and Quercus ilex as well as the average. We show the existence of two classes of average profiles built from the distribution of the maximal values of the GSI (Fig. 8). For the first class, the values of the GSI are superior to 100 µm for the grown eucalypti and only of 30 µm for the Quercus ilex. This profile is quasi-symmetric and little contrasted. For the second class, the values of the GSI are lower than 100 µm for the grown eucalypti and only 30 µm for the Quercus ilex. This profile is characterized by a profile more or less flat translating a uniform distribution of the stress of growth and shows that these trees are without wooden presence of reaction.

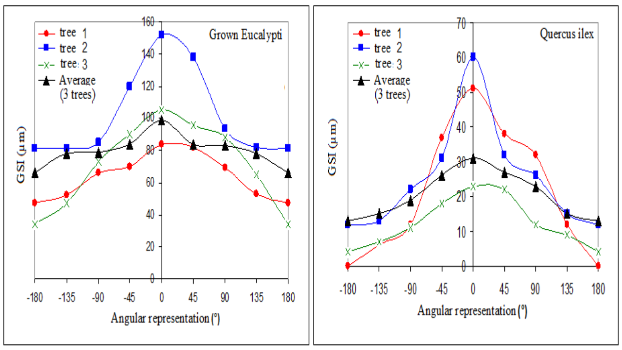

Fig. 8. Experimental Profile of the GSI centred on the maximal value for three trees and the average

B. *Tensile resistance and in the distribution of crack of wood the grown Eucalyptus and the Quercus ilex*

1) Failure stress of tensile

The massive wood of grown eucalypti and of Quercus ilex presents a fragile behavior with a failure stress the Quercus ilex (σ_r = 181.25 MPa) green bigger than that of grown eucalyptus (σ_r = 85.42 MPa). The table. 3 groups together the average values of the failure stress and its coefficient of variation of every tree of every essence.

Table 3. Summary table of the failure stress of wood of grown eucalypti and Quercus ilex with its coefficient of variation (CV%)

Species	Grown Eucalypti		Quercus ilex	
N° trees	**σ_r (MPa)**	**CV%**	**σ_r (MPa)**	**CV%**
1	88,67	25	158,69	16
2	81,26	34	226,90	27
3	86,31	32	158,18	17
Average	85,42		181,25	

2) The Resistance in the distribution of crack

Fracture toughness G1c, in terms of energy release rate of refund of energy represents energy necessary to create two surfaces of value bda, where B is the thickness and da the unit increment length of crack, is given by:

$$G_{1C} = \frac{P^2}{2b}\frac{\partial C}{\partial a}$$

For the approximation of the curve of compliance according to the length of the crack has, we chose a smoothing of the experimental points by using an exponential function, what makes it possible to obtain the value of dC/da.

The table 4 groups the average values of the fracture toughness and its coefficient of variation of every tree of every essence.

Table 4. Summary table of the fracture toughness G1c of wood of grown eucalypti and Quercus ilex with its coefficient of variation (CV%)

Species	Grown eucalypti		Quercus ilex	
N° trees	**G_{1c} (J/m^2)**	**CV%**	**G_{1c} (J/m^2)**	**CV%**
1	357	6	454	7
2	339	6	434	8
3	326	6	433	4
Average	341		433	

The fracture toughness shows that the massive wood of Quercus ilex is tougher than the grown Eucalyptus. This could be explained by the anatomical differences of these two leafy species, the age and the particular structure (tension wood) and also by random ruptures in the wood.

3) Relation between the fracture toughness, the failure stress and the growth stress of indicators

The Fig.9 represents the average of the experimental fracture toughness of the massive wood and the failure stress of rown eucalypti and the Quercus ilex according to the growth stress of indicators. We observe that the fracture toughness and the failure stress are independent from growth stress of indicator GSI.

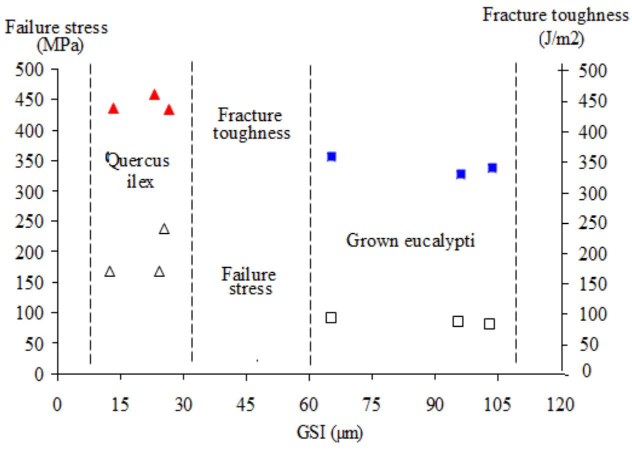

Fig.9. Fracture toughness and failure stress by tree of massive wood according to growth stress of indicator GSI.

C. *Mechanical properties*

The table.5 presents the main results concerning the modules of dynamic elasticities of the studied trees. The indicated values correspond to averages obtained on 90 specimens tested for every essence of every tree.

Table 5. Mechanical characteristics of the wood of grown eucalypti and of Quercus ilex

	Grown eucalypti		**Quercus ilex**	
	Moy	**Ecart-type**	**Moy**	**Ecart-type**
E_t(MPa)	14300	2663	15100	1425
G_t(MPa)	800	439	1300	435
E_b(MPa)	13400	2476	14300	1366

E_t: Module of elasticity of Timoshenko, E_b: Module of elasticity of Bernouilli et G_t: Module of shearing of Timoshenko

The grown eucalypti and the Quercus ilex present an almost similar average rigidity. J. GÉRARD [6] respectively showed that the value of the module of static elasticity in flexion four points is of 14GPa for the Quercus ilex of the Hérault and of 12GPa for eucalyptus of Congo.

CONCLUSION

The study of the growth stress indicator (GSI) showed in a clear way that these stresses show themselves in different manners for both sorts. This can be explained by the presence of the wood of tension, by the age of the tree and by the speed of fast growth for the grown eucalypti and slow for the Quercus ilex. The distribution of the values of the GSI with regard to the maximal value loosened two different classes of profiles towards an angular symmetry. The profile of the first class, is almost symmetric and a little bit contrasted, whereas the profile of the second class is more or less flat.

We compared the failure stress of the massive wood of grown eucalypti and of Quercus ilex ($\sigma_{r\ E.grandis}$ = 85,42 MPa and $\sigma_{r\ \text{Chêne vert}}$ = 181,25 MPa) and their tenacity ($G_{1c\ E.grandis}$ = 341 J/m^2, $G_{1c\text{Chêne vert}}$ = 440 J/m^2) determined by the compliance method. This method verifies that G_{1C} is an intrinsic characteristic of the material. The massive wood of Quercus ilex is firmer than that of the grown eucalypti. These intrinsic parameters are independent from growth stress indicator (GSI).

The made measures (GSI, failure stress and the fracture toughness) serve as descriptors and indicators of the behavior of wood and predictors checks of the fissuring, they have a big importance at the level of the users, who can also help to understand the physical aspects to improve the potentialities of these wood (genetic and silvicultural, sorting, classification of brought (shot) down wood.).

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