Eucalyptus drying process: qualitative comparison of different clones cultivated in Italy

L. Travan[1], O. Allegretti[2] & M.Negri[3]

Abstract

Kiln-drying process of Eucalyptus timber can be critical because of the possible occurrence of collapses, fissures and other defects related to the moisture decrease. The occurrence and the incidence of these defects is related to both the drying process and the wood, namely species and/or clone and individual factors related to the site of growing.

Nardi International Srl and IVALSA-CNR, Trees and Timber Institute, performed various drying cycles on four clones of Eucalyptus grandis, Italian grown, in order to determine the quality decrease due to the process.

Prudential basic drying schedules were chosen according to the technical literature available and the tests were focused to compare the behaviour of the various clones.

Moreover, some tests were performed by using both conventional drying kilns (Nardi International Srl and IVALSA-CNR) and continuous press-dryer (IVALSA-CNR).

The quality of the sawn timber (planarity, checking, deformations, *etc*.) was measured before and after the drying process. The results showed that relevant differences exist among the clones and that it is possible to increase the final quality of sawn timber by choosing a suitable drying schedule.

1 Introduction

Eucalyptus grandis has been tested in Italy for forestry purposes since the last century, but the scarce utilisation of timber until now did not provide experiences concerning drying. According to literature a lot of technological problems of this species are strictly related to a suitable drying process, which is the most relevant step for the utilisation of *E.grandis* as solid timber raw material.

[1] Technological Department, livio.t@nardi.it
Nardi International Srl, Via Ritonda 79, 37047 San Bonifacio (Verona), ITALY
[2] Phd Researcher, allegretti@ivalsa.cnr.it
IVALSA-CNR, Trees and Timber Institute, S.Michele all’Adige, ITALY
[2] Phd Researcher, negri@ivalsa.cnr.it
IVALSA-CNR, Trees and Timber Institute, S.Michele all’Adige, ITALY

This comparative kiln drying tests performed on *E. grandis* clones grown in Italy are to be considered a first approach to the problem, investigating the behaviour of each clone in different kiln conditions, in relationship to drying quality.

Of course a successive characterisation should later be envisaged, limited to the clones which have given a good response to this test.

The emergence of the drying quality issue, assessed in accordance to the EDG recommendation, is relevant to the subsequent processing of dried timber. In fact part of the material tested was then used for manufacturing Poplar-Eucalyptus mixed glue laminated timber (Castro *et al.*).

Quality grading is not only used to select material for subsequent uses, but also define a more or less successful kiln run in the sense of moisture content spread, moisture gradient, casehardening and other drying defects occurrence. In this case it was used as a method of classification of the drying response of each clone.

2 Background

The drying behaviour of Eucalypts as well as of many other species, and the related problems are basically different during the first (above the fibre saturation point) and the last stage (below the FSP) of drying process. For example collapses are typically related to the first stage of drying while degradations due to the shrinkage phenomena are produced during the last drying stage.

The kiln drying of Eucalypts has been for a long time considered a two-stage process: pre-drying in mild conditions to fibre saturation point and then conventional drying in controlled regimes. This method is slow and, in dry climates, can induce degrade during pre-drying.

Different experiences, in north of Spain (for *Eucalyptus globulus*) and in south America countries (for *Eucalyptus grandis*), suggest to pre-dry Eucalyptus for a long period in air conditions not exceeding the 30° C and 2° C psychometric difference with 1 m/sec air flow speed (Baso *et al*, 2000; Vermaas, 2000) Such drying treatment allows to reduce the defects of the first stage of drying but it is also very expensive comparing to a natural pre-drying in non-controlled air conditions and it is practicable only on industrial scale. At present, the tendency is drying directly rather wet material using appropriate climatic conditions in the kilns.

The choice of the drying regimes in our tests was of course based on the existing literature concerning Eucalypt processing (Kauman, Gerard, Jiquing and Wang, 1995) and the drying schedules included in the publication by Campbell (Campbell, 1980) “Index of Kiln Drying Schedules for Timbers Dried in Australia” (updated by Rosza and Mills, 1991). Much of the parameters used in the test runs where then re-viewed and corrected according to every day practical information obtained from kiln operators throughout the world.

The extensive presence of Nardi kilns in regions where plantation-grown *Eucalpytus grandis* is diffused, facilitated the exchange of information. Drying schedules can in fact change consistently for the same species in relation to different provenances but also to many other factors including the quality expectations of the user: it is not at all unusual to find, even in scientific literature, very different schedules for the same wood type.

The huge variability of the genus Eucalyptus intrinsically complicates the research of an appropriate drying schedule.

The main issues concerning Eucalyptus drying are: *growth stresses* which can induce later gradient stresses but that mainly cause extensive splitting of boards and strong deformation, before drying already, *surface checking* due to high shrinkage rates particularly in backsawn boards and *collapse* caused by capillary tensions in wood cell lumens when moisture content is higher than fibre saturation.

Collapse is more pronounced in the radial board then in the tangential ones because of the better permeability in radial direction and it can be reduced by reconditioning treatment at the end of drying (better still at 20% moisture content level).

The growth stresses are related to the grow conditions of the tree and to the species (it is more pronounced in fast grown trees). They produce radial checks from the pith to the bark in the round timber of the felled tree. The degradations produced by growth stresses on the sawn boards are considered one of the main problems for the utilisation of Eucalyptus for timber. Their effects are quite different in tangential and radial boards: in the tangential and sub-tangential ones the stresses produce splitting and bow deformation; in the radial one they produce mainly crook deformation. To solve the problem of growth stresses, caused by longitudinal tensions in the annular peripheral volume under the bark, some methods, such as storage under water or ringing, are under investigation but they seem not able to provide a definite solution. At the moment the best solution to reduce the growth stresses damages seems to be in the appropriate sawing pattern procedure of the round timber suitable to maximise the number of radial boards rejecting the peripheral side of the log.

Surface checking can of course be prevented by appropriate drying methods.

Another issue related to drying is the measurement reliability of the moisture content of the boards: electrical hygrometers are extensively used, as compared to oven sampling, but can induce errors especially in the application of drying schedules to green sawn timber. When the moisture content is below the fibre saturation point we can obtain a rather precise indication of moisture content measured by the moisture meter, while above it the results are strongly biased by increasing errors. Beside this, the statistical classification of timbers into groups, each represented by a resistance curve, as done by many moisture meter manufacturers, does not take into account that several species have a different electrical behaviour which does not fit at all in these groups (Geissen and Noack, 1991). Some reference will be made to this aspect later in the paper.

3 Materials and methods

The trials were performed at two different sites: A) at Nardi International Srl in San Bonifacio and B) at IVALSA-CNR, Trees and Timber Institute, (S.Michele all’Adige, Trento – Italy).
The material, derived from the cutting of different *Eucalyptus grandis* clones (358, 330, 7, 329) and *Eucalyptus trabutii* planted in a trial plot in Salerno (Southern Italy).

All the material consists in boards 2 m long, 20 mm thick and different width depending on the dimension of the original round timber and on the sawn pattern. From the sawing process to the drying tests the stacks were pre-dried for a variable period ranging from 22 days until 3 months in a shaded environment. This phase was nor planned neither controlled but it was due to the organisation of delivering of the testing material.
The climate in the spring and early summer season being rather dry, a rather rapid water evaporation from the boards took place, fortunately not causing any additional defect to the rather intense splitting and bow deformation by growth stresses. Initial moisture (MC) ranged from approximately 50% to 20% (oven samples) according to the period of the test-trials
At Nardi International Srl the testing conditions were as follows:

- three stacks were dried in a small laboratory kiln of conventional type
- kiln configuration: outer dimensions: 2350 mm x 2400 mm x 2750 mm, with two 800 mm fans with 3kW motors at 1400 rpm (air speed: approximately 2.6-2.7 m/s). Heating by electrical resistances 12 +12 kW. Dehumidification through 100mm diameter vents (2+2) on the roof and humidification either by steam or by cold water spray. Six moisture content probes, two temperature;
- the three stacks had the following dimensions: 1500mm x 800mm x 900mm (boards being 30mm x 1500mm x 150-300mm). Stickers had 15mm thickness. In all the three stacks, the layers were 17. Plenum width was approximately 550-660mm. Baffling was not considered necessary, as the stack fitted snugly in the lab kiln;

At IVALSA-CNR, Trees and Timber Institute, the testing conditions were as follows:

- four stacks were dried in a laboratory kiln of conventional type;
- kiln configuration: total internal volume 16.8 m^3; stack dimension: 400 x 120 x 100 cm; stack volume: 2.5 - 4 m^3; air volume: 12.7 - 14 m^3; filling coefficient 21 ÷ 30 %. Single fan (∅900 mm, powered by a 5.5 kW motor) located in the back side of the kiln providing an horizontal air flow. Two vents (300 x 400 mm) are located on the left and right side of the fan. The kiln is heated by means of a gas boiler (837360 kJ/h) supplying thermal oil (up to 240°C) flowing throw the heating coil. The humidity is provided by water

and/or steam. The flow of water is about 3 kg/min and the flow of steam is up to 33 kg/hour.

- Control system: six couple of electrodes for the measurement of the wood moisture content; two psychrometers in the middle side of the left and right wall measure the dry and wet temperature. stacks dimensions. The stickers were 15mm thick.

At IVALSA-CNR, Trees and Timber Institute, one small stack was also tested into a small (0.4 m^3) continuous vacuum press-dryer. In this case the drying conditions consist on a temperature of 60 °C.
Final MC was programmed as 12% in the schedules.
The clones of *Eucalyptus grandis* in the stacks were randomly distributed throughout the stack to avoid specific climate conditions. No single clone stacks was possible due to scarcity of material available.

3.1 Drying schedules

The schedules used in the drying trials are reported in Table 1.The schedules were mainly based on existing literature. As the drying behaviour of the Italian clones was unknown, and the boards were all presenting intense splitting degrade caused by growth stresses, the drying schedules were initially tested using milder climatic parameters (end temperature: 60° C). After the first cycle was completed and it was noted that initial degrade (splitting, collapse) was not enhanced during drying, the schedules were slowly hardened, by using more severe kiln conditions (end temperature: 70° C). The drying phase was of course preceded by a warm-up at high humidity levels and it was followed by equalising phase to even up MC% spread.

Table 1 – Drying schedules

	IVALSA		Nardi 1		Nardi 2		Nardi 3	
MC	***Temp.°C***	***EMC %***	***Temp.° C***	***EMC%***	***Temp.° C***	***EMC%***	***Temp.° C***	***EMC%***
>50	-	-	45	15.0	-	-	-	-
50-45	-	-	45	14.5	-	-	-	-
45-40	-	-	45	14.0	-	-	-	-
40-35	-	-	45	13.0	-	-	-	-
35-30	-	-	45	12.0	-	-	-	-
30-25	50	11.4	48	10.0	50	13.0	-	-
25-23	55	9.0	52	8.5	50	12.5	-	-
23-20	55	9.0	52	8.5	52	11.5	-	-
20-19	60	6.5	58	6.5	54	10.5	55	12.5
19-18	60	6.5	58	6.5	54	10.5	57	11.5
18-17	60	6.5	58	6.5	57	8.5	57	11.5
17-16	60	6.5	58	6.5	57	8.5	59	10.5
16-15	60	6.5	58	6.5	62	6.5	63	8.5
15-14	60	6.5	65	5.0	62	6.5	67	6.5
14-12	60	6.5	65	5.0	68	5.0	70	5.0
Initial MC	20%		40%		16%		16.30%	
Final MC	12%		12%		12%		12%	
Duration	7 days		9 days		7 days		3 days	

3.2 Hygro-metrical control

The control of the process was performed by the means of resistive hygrometers, as usual on such drying machines. Comparative measurements on moisture content of *Eucalyptus* specimens carried out both with hygrometers and by gravimetric procedure provide the amplitude of uncertainty of hygro-metrical controls.

3.3 Splitting and deformation on sawn timber

The splitting of the ends on sawn timber was evaluated by grading the sawn timber as follows: low = length of split < 1/3 of board length; moderate = from 1/3 to ½; severe = longer than ½ length.

The shape of sawn timber was measured by mean of a three point reference bar, one meter long, able to carry out a one-shot measurement.

The bar is instrumented with digital gauges connected with a data-logging system, and it is able to measure at the same time bow, cup and twist (see Figure 1). Crook was not measured because of its low presence and amplitude. The shape was measured on a large sample of sawn timber before and after the drying process.

The initial deformations (DEF.i) are reported as absolute value of the distance from the central measurement point from the plane determined by the three reference points. According to the figure the three reference point are 10 and 100 cm distanced from each other[3].

After the drying process the final deformation (DEF.f) were measured and are reported as percentage variation (d DEF.) respect to the initial average value:
d DEF.= (DEF.i –DEF.f)/av. DEF.i x 100.

According to such formulation a negative variation means an increase of the deformation, a positive value a decreasing deformation.

3.4 Quality of dried sawn timber on small specimens

The tests on the quality of drying process are carried out according to the EDG-European Drying Group Recommendations.

The main tests performed at present are the following:

- internal stresses;
- check occurrence;
- collapses;
- moisture gradients.

[3] The base distance is for cup 10 cm, for bow 100 cm, 10 cm on a distance of 100 cm for twist.

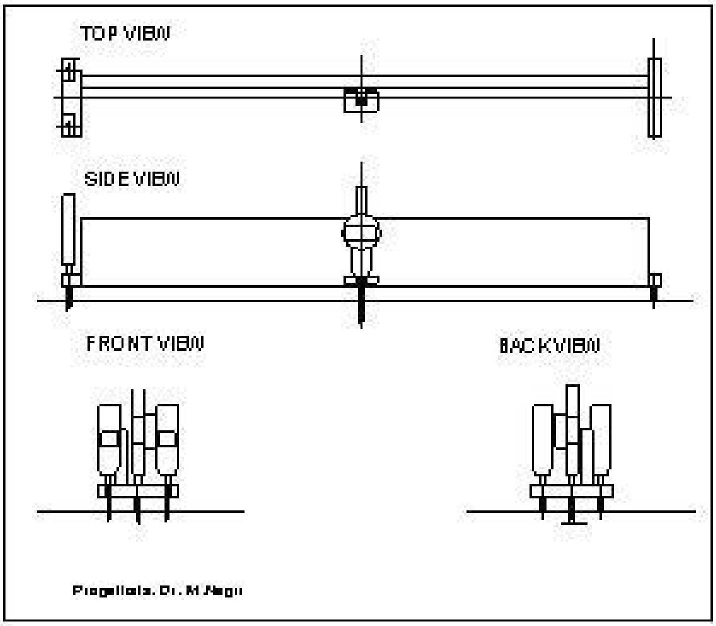

Figure 1 - The reference bar instrumented with gauges

4 Discussions and results

4.1 Pre-drying

The initial average MC in the green timber is about 90% for the whole sample.
On a sample of three stacks, the pre-drying period (22 days long) was checked. As shown in the Figure 2, during the first period of the checked pre-drying phase, the rate of MC loss is very high. (-6.7%/days). Such rate starts decreasing when the average MC is around 30% and remains on a value of about 1%/days until the end of the pre-drying period.

4.2 Reliability of hygro-metrical control

The resistive measurement is compared to the actual oven-dried samples in the following Table2, regarding one stack only.
It is interesting to note that by using the compensating factor normally employed for measuring *Eucalyptus spp.* in general, we noticed a great difference in electronic behaviour between the various clones. Clone 7 and 330 were read with a great degree of accuracy both wet and dry, clone 329 gave quite a good reading under FSP, while 358 and *E.trabutii* gave very hap-hazard readings, not only in green wood above FSP (fiber saturation point) where it is known electronic readings are unreliable but also in dried wood. The samples, although repeated, cannot be considered sufficient to confirm this behaviour. A further investigation seems necessary to process new compensation curves for the electronic measurement of these clones.

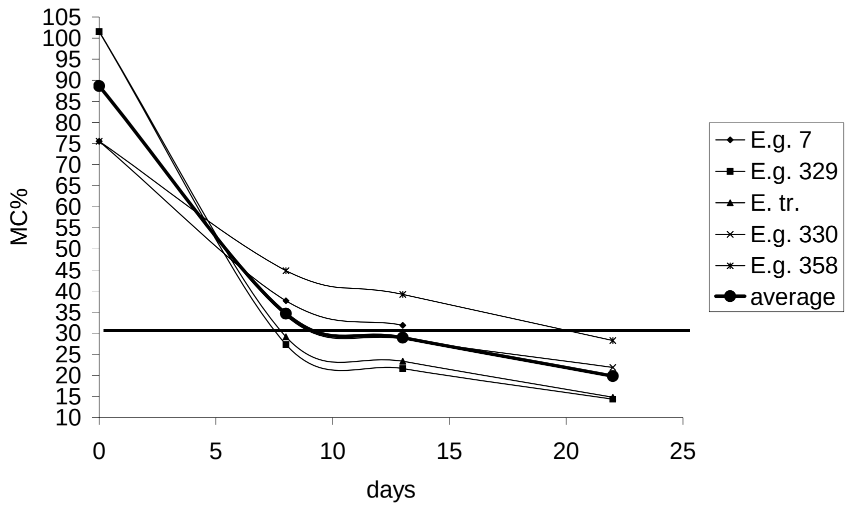

Figure 2 – Pre-drying phase

Table 2 - Resistive measurements compared to the actual oven-dried samples

	MC above 30%			MC below 30%		
CLONE	**MC electr.%**	**MC oven %**	**Absolute Error %**	**MC electr.%**	**MC oven %**	**Absolute Error %**
***E.g.* 329**	43.8	30.8	**13.0**	12.8	13.6	**-0.8**
***E.g.* 358**	55.6	37.1	**18.5**	19.7	15.9	**3.8**
***E.g.* 7**	49.0	47.1	**1.9**	12.9	12.4	**0.5**
***E.g.* 330**	51.2	49.9	**1.3**	13.1	13.2	**-0.1**
E.trabutii	44.6	21.9	**22.7**	15.1	14.0	**1.1**

4.3 Splitting due to growth stress

Between sawing and drying processes many splits occurred, due to internal growth stresses. Splitting by growth stresses was analysed extensively on a sample, (one stack). Figure 3 reports the intensity of splitting.
All clones in this stack were affected by growth splits, from the beginning, and remained unchanged after drying in the laboratory kiln. Clone *E.g.* 7 and *E.g.* 358 were the less affected; *E. trabutii* and clone *E.g.* 329 the most.

4.4 Deformations

The sawn wood showed many large deformation during the time between sawing and drying process. We found two kind of initial deformation (Figure 4):

- cup and (probably) twist were due to shrinkage phenomena that began to appear when the MC decreased below 30% ;
- a very strong bow deformation in 90% of the boards due to growth stresses.

The last deformation is one of the most relevant defects for this species.

The drying process influenced in different ways the different kind of deformation and different clones.

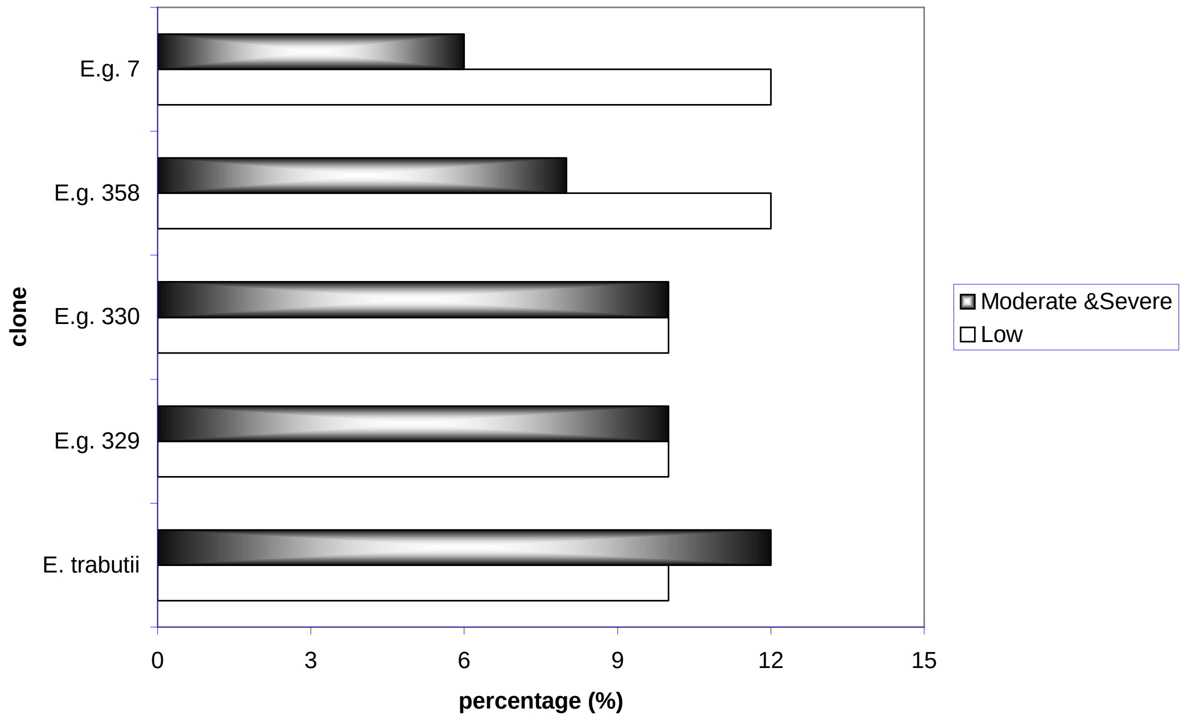

Figure 3 – Splits on clones

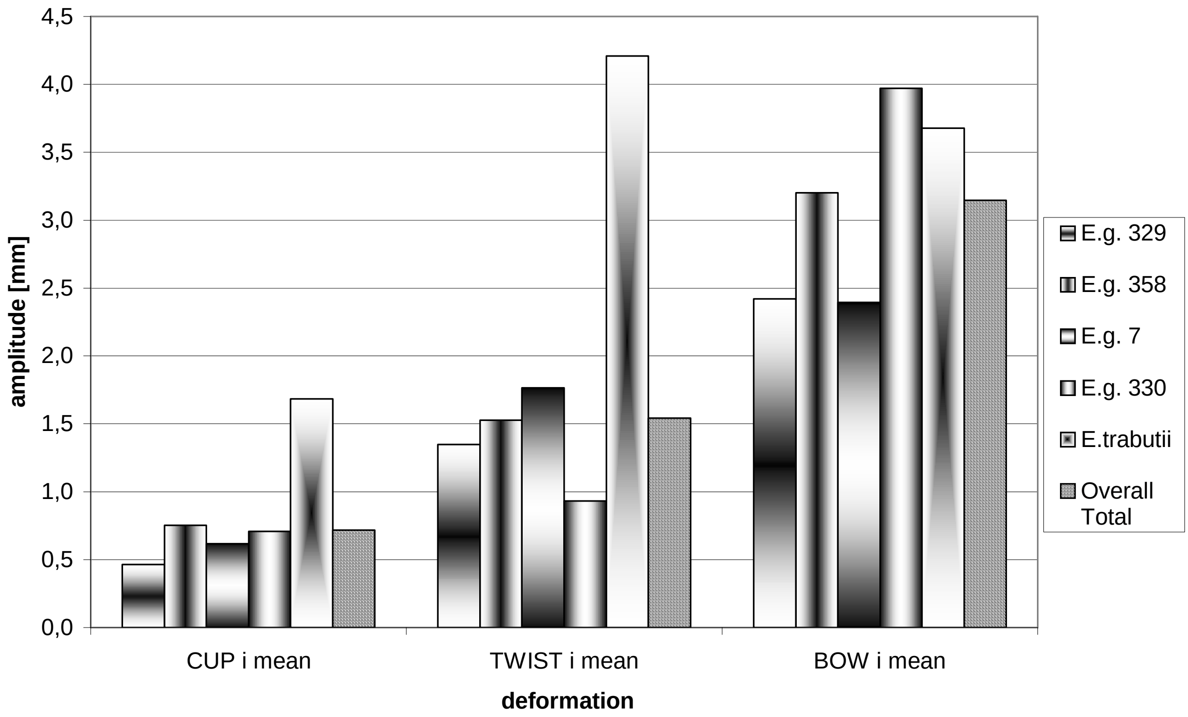

Figure 4 – Amplitude of initial deformations divided according the clone. These deformations occurred between sawing and drying processes

As shown in Figure 4 the drying process not only did not provide any increment in bow deformation, but the process reduced the amplitude of this defect. This phenomenon is due to the force[4] on the stacks during the drying process. The biggest benefits were reached by the *Eucalyptus grandis* clones 330 and by the *Eucalyptus trabutii*.

On the other hand, with the exception of *Eucalyptus trabutii* that was in any case improved, the drying processes increased the cup and the twist deformation.

At the moment there is no significant evidence of the influence of the different drying processes on the wood quality. In some cases the continuous vacuum press-dryer seems to improve the final planarity of the dried timber.

[4] In the conventional oven dryer, a load was placed on the stacks. The press-dryer pushed the stack with the rubber membrane with a force related to the level of vacuum

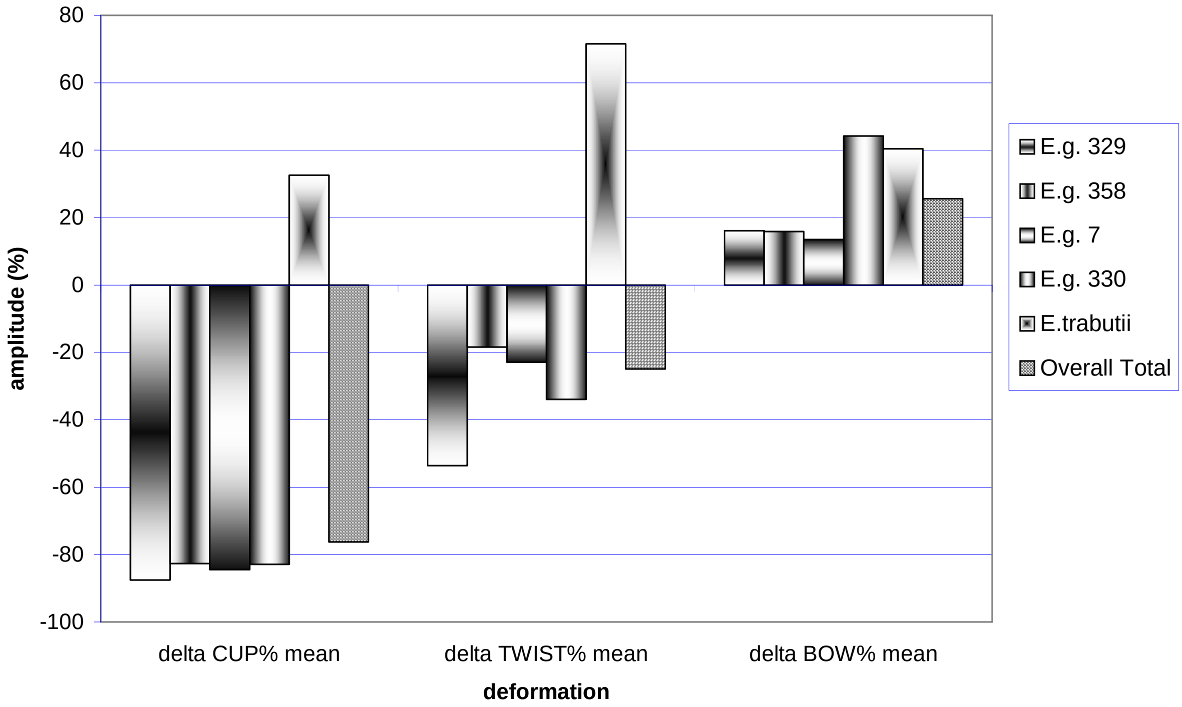

Figure 5 – Percentage variation of deformations divided according to the clone

4.5 Other defects

4.5.1 MC gradient

No significant difference among clones and drying cycles was found: the average final MC was 12%; the shell MC was 11.5%, the core MC was 13.1% and the MC gradient was 1.6%. According to the EDG recommendation the material should be considered as class E (exclusive).

4.5.2 Casehardening

The slicing tests for the evaluation of casehardening according to the EDG recommendation were performed on 32 specimen coming from the dried timber after the conditioning treatment.) 90% of all gap openings were smaller than 2 mm. According to the EDG recommendation the material should be considered as class Q (quality).

4.5.3 Collapses

All the clones of *Eucalyptus grandis* undergo a low or no collapse degradation. The *Eucalyptus trabutii* was instead deeply damaged by from moderate to severe collapse, mainly occurred during the pre-drying phase.

5 Conclusions

According to how reported in literature, the main problem we have found in our experience was the degradation of the Eucalyptus timber during the first pre-drying phase due to the growth stresses. Those stresses produced huge splits and bow deformations mainly in the tangential board of all the clones.

At the moment no significant difference seems to exist between clones. Only the *E. trabutii* quality of sawn timber at the end of the pre-drying period showed collapses and growth stress degradations significantly higher than the other specie.

In many cases we have found that a well performed drying treatment can improve the quality of the end-product even if the low quantity of the tested material did not permit yet to have statistical confirmation.

References

Campbell G.S., , “Index of Kiln Drying Schedules for Timbers Dried in Australia”, C.S.I.R.O., Australia, 1980

Baso C., Bouzòn A. & Furones P. “Metodologia y primera experiencia de presecado y secado de *Eucalyptus globulus*”, Centro Universidad de Vigo, Proyecto Iberoeka de I+D, confidential report., 1999-2000.

Baso C., Casas J.M., Furones P. & Bouzòn A. “Steam treatment to improve the quality and increase the rate of drying of *Eucalyptus globulus* Labill.. Proposal and execution of a test on quarter-sawn boards”, Proceedings of 4th Cost E15 Workshop, 30th and 31st May 2002, Santiago de Compostela, Spain.

Du Q.P., Geissen A &, Noack, „Die Genauigkeit der elektrischen Holzfeuchtemessung nach dem Widerstandprinzip“, *Holz als Roh- und Werkstoff*, 49 pp.1-6, 1991.

Du Q.P., Geissen A. & Noack, “Widerstandkennlinien einiger Handelshölzer und ihre Meßbarkeit bei der elektrischen Holzfeuchtemessung“, *Holz als Roh- und Werkstoff*, 49 pp.305-31, 1991.

Kauman W.G., Gerard J., Jiqing H. & Huaijun W., “Processing of Eucalypts” *Commonwealth Forestry Review*, 74 (2) pp. 147-154, 1995.

Lima J.T., Breese M.C. & Cahalan C.M., “Variation in wood density and mechanical properties in Eucalyptus clones, proceedings of the Future of Eucalypts for wood products”, IUFRO, 19-24th march 2000Australia, pp. 282-290, 2000.

Nardi in collaboration with European drying Group, 1994, Assessment of drying quality of timber, pp 31.

Rosza A. & Mills R.G., “Index of Kiln Drying Schedules”, C.S.I.R.O., Australia, pp. 30, 1991.

Santos J.A. “Recovering dimension and form in collapse distorted boards”, Proceedings of 4th Cost E15 Workshop, 30th and 31st May 2002, Santiago de Compostela, Spain.

Vermaas H.F., “Drying of Eucalypts with special reference to young, fast-grown plantation material”, 1° seminàrio internacional sobre produtos solidos de madeira de alta tecnologia, Decembre 1988, Brasil, pp. 107-118, 1998.

Vermaas H.F., “A review of drying technology for young fast –grown eucalypts, proceedings of the Future of Eucalypts for wood products”, IUFRO, 19-24th March 2000 Australia, pp. 193-203, 2000.

Vermaas H.F., “State of the art and latest technological advances in the drying of fast-grown eucalypts”, Proceedings of 4th Cost E15 Workshop, 30th and 31st May 2002, Santiago de Compostela, Spain.