Silva Lusitana ***9****(2): 191 - 198, 2001*
© EFN, Lisboa. Portugal

Sawing Optimisation for Block Panel's Production of Portuguese West Littoral Maritime Pine Radial Boards[1]

José Campos* and Mário Tavares**
* Forest Engineer
** Senior Researcher
Departamento de Silvicultura e Produtos Florestais. Estação Florestal Nacional,
Rua do Borja, 2, 1399-051 LISBOA

Abstract. Increasing wood demand as raw material and the necessity to adjust each end use to the characteristics and properties of each wood has been improving the employ of round wood of small dimensions as well as low quality sawn wood. In this case we may include radial boards and the two adjacent tangential boards, even if obtained from large round wood.

The available technological processes, mostly based on the identification and location of one of the most important wood defects - the knots - tend to maximize the utilisation level of small wood so as to improve quality and productivity.

Maritime pine radial boards are the worst sawn pieces concerning presence of knots on more or less distant whorls along the stem. However, although being an unfavourable characteristic of the species, knot concentration on bands, separated by long annual height growth, allows the utilization of board wood in between.

This paper aims to estimate mean values of number, size, location, condition and shape of knots on a sample of 161 radial boards from 38 maritime pine trees, collected in three pine forests located along the Portuguese littoral west coast. Based upon data collected in the stand and in the sawmill, it's also simulated the optimization of clean wood for sawing, in order to produce block board panels. To simulate lath profit, was taken account of tree provenance, statute in the stand, *dbh*, board mean diameter, number of knot bands and log ranking in the tree. The lath dimensions usually utilized by block boards panels industry were considered.
Key words: *Pinus pinaster*; knots; laths profit; block board panels; modelling

Sumário. A crescente procura de madeira como matéria prima e a necessidade de adequar as características e propriedades de cada tipo de madeira ao uso final pretendido, tem promovido o emprego de madeira redonda de pequenos diâmetros e de madeira serrada de menor qualidade. As tábuas radiais e as duas tangenciais adjacentes, mesmo se extraídas dos toros de maiores dimensões, podem estar, naturalmente, incluídas neste caso.

Os processos tecnológicos disponíveis, a maioria baseados na identificação e localização de um dos mais importantes defeitos da madeira - os nós, tendem a maximizar a taxa de aproveitamento de peças mais pequenas de modo a que se atinjam melhores qualidade e produtividade.

As tábuas radiais de pinheiro bravo são as peças serradas de pior qualidade no que respeita à presença de nós ao longo das tábuas. Contudo, sendo uma característica tecnológica desfavorável da espécie, a concentração de nós em bandas, separadas por longos crescimentos

[1] Scientific paper presented in *poster format* at the 4th meeting of COST E10 action – *Wood properties for industrial use*. Bordeaux, France – March 7-9, 2001.

Corresponding author E-mail: josemacampos@clix.pt

em altura, permite uma mais fácil utilização da madeira nos entrenós.

Este trabalho pretende estimar o valor médio do número, tamanho, localização, estado e forma dos nós de uma amostra de 161 tábuas radiais extraídas de 38 pinheiros provenientes de três matas localizadas no litoral oeste de Portugal. Simula-se, ainda, a optimização da serragem de madeira isenta de nós para o fabrico de painéis de lamelados colados a partir da informação disponível na mata e na serração. A simulação do aproveitamento em ripas é efectuada através da proveniência, estatuto da árvore no povoamento, *dap* das árvores, diâmetro médio das tábuas, número de nós por banda e posição do toro na árvore. Consideram-se as dimensões de ripa mais utilizadas por esta indústria.

Palavras-chave: *Pinus pinaster*; nós; aproveitamento em ripas; lamelado colado; modelação

Résumé. La demande croissante en bois comme matière première, et la nécessité d'ajuster les caractéristiques et propriétés de chaque type de bois à l'usage final prétendu, pousse l'emploi de bois rond avec des plus petits diamètres et de bois sciés de qualité inférieure. Les planches radiales et les deux tangentielles adjacentes, toutes extraites des billons de plus grandes dimensions sont, naturellement, inclues dans ce cas.

Les procédures technologiques disponibles, la plupart basées sur l'identification et la localisation d'un des plus importants défauts du bois – les nœuds, tendent à maximiser la taxe de profit des pièces plus petites de façon à atteindre une meilleure qualité et productivité.

Les planches radiales de pin maritime sont les pires pièces en ce qui concerne la présence de nœuds en verticilles sur les tiges. Toutefois, ceci étant une caractéristique technologique défavorable de l'essence, la concentration des nœuds en bandes, séparées par des longues pousses en hauteur, permet une utilisation du bois plus facile au niveau des entre-nœuds.

Ce travail prétend estimer la valeur moyenne du nombre, grandeur, localisation, état et forme des nœuds d'un échantillon de 161 planches radiales extraites de 38 pins de trois forêts le long du littoral ouest du Portugal. On simule aussi l'optimisation du sciage du bois sans nœuds pour la fabrication de lamellés collés, d'après l'information disponible en forêt et en scierie. La simulation du profit en planches est effectuée en fonction de la provenance, du statut et du *dhp* des arbres et du diamètre moyen des planches, nombre de nœuds par bande et position du billon sur l'arbre. Les dimensions de planche les plus utilisées pour cette industrie sont considérées.

Mots clés: *Pinus pinaster*; nœuds; profit en planches; lamellé collé; modélisation

Introduction

Littoral Portuguese maritime pines grow by one or two annual cycles - the first one during spring, corresponding to earlywood layer in the annual ring, the second one in autumn corresponding to latewood. These two shoots inscribe, at least the first one, a thin band of branches placed close to the start of the annual stem growth. Of course its band of knots will be found on both faces of radial board and, at least, on one face of next two aside tangential boards.

Production of block board panels from maritime pinewood is not too exigent concerning wood quality requirements. The available technological process by-pass the contrarieties that maritime pine knots globally cause on the quality of the final product, when excluding whorl bands along sawn boards. This process makes possible to optimize the final quality of block boards by the complete elimination of knots. On radial boards most of them are sound knots and, on a large amount of the two first tangential ones, loose knots can also be found. The second tangential boards can be reserved for a more noble use.

This paper intends to quantify mean values of number, size, location, condition and shape of knots on the radial board. It also intends to simulate the maximum profit on 3 to 10 cm width laths sawn on radial boards, without sound or loose knots, in order to obtain raw material to reconstruct block board panels.

Material and methods

A sample of 38 trees was collected in the west provenances *Camarido* National Forest (MNC) - 10 trees, *Leiria* National Forest (MNL) - 18 trees and *Comporta* Forest (MC) - 10 trees (Table 1). Age classes (30, 50 and 70 years old) and tree statutes inside the stand (***d*** - dominated, ***m*** - medium and ***D*** - dominant) were considered. These variables were used as indicators.

From a sample of 161 logs with 2.60 m length were sawn the same number of radial boards. On each board face were measured the coordinates of each knot regarding left and top board limits and its vertical and horizontal diameters. These data permits to evaluate number and surface of knots on each board face and to have enough information to simulate lath sawing. This sawing simulation was done considering a minimum of 15 cm length and 30 to 100 mm width, dimensions compatible with laths industrial process.

Lath profits were evaluated concerning profitable wood surface on each radial board; knotted and non-knotted wood waste was also evaluated.

Linear multiple regression (backward stepwise) was performed using *Statistica* computing application.

Table 1 – Trees and sawn boards sample size

provenance	age class	number of	tree statute *d*	tree statute *m*	tree statute *D*	sub total
MNC	30 years	trees	0	2	2	4
		logs	0	7	9	16
	50 years	trees	1	1	1	3
		logs	5	6	7	18
	70 years	trees	1	1	1	3
		logs	3	7	6	16
		trees	2	4	4	10
		logs	8	20	22	50
MNL	30 years	trees	2	2	2	6
		logs	2	8	10	20
	50 years	trees	2	2	2	6
		logs	6	8	10	24
	70 years	trees	2	2	2	6
		logs	6	11	13	30
		trees	6	6	6	18
		logs	14	27	33	74
MC	30 years	trees	0	2	2	4
		logs	0	2	8	10
	50 years	trees	1	1	1	3
		logs	1	4	5	10
	70 years	trees	1	1	1	3
		logs	4	6	7	17
		trees	2	4	4	10
		logs	5	12	20	37
total number of trees			10	14	14	38
total number of logs			27	59	75	161

Number, location and characteristics of knots

Some mean values can be evaluated on the whole sample regarding knots characteristics; concerning this approach must be noticed that all the boards were considered as an allotment of pinewood.

It's interesting to note that mean board surface is around 0.6 m^2 and includes about 19 knots. They are placed quite close to the pit, so their mean diameter is rather small (25 mm).

There are 3.5 knots per each of the 5.4 knots bands along the board (Table 2).

Table 2 – Number, location and size of knots on the board

data	average	std dev
board surface (m^2)	0.57	0.17
number of knots/board	19.0	5.2
number of knots/board surface(m^2)	37.0	15.7
number of knots band/board	5.4	1.8
knots band width (mm)	65	59
mean distance between knots band (mm)	354	195
number of knots/band of knots	3.5	1.7
mean diameter of knots (mm)	25	17
surface of knots/board surface(m^2)	0.021	0.012

Mean bands width is quite thin (6.5 cm) but presents a lot of variation. Mean distance in between correspond to the amount of clean wood prowls about 35 cm; this population is also very variable.

Analizing these numbers can be noted that there are about 37 knots per board square meter in average; it means that they take place in about 2% of each board. Numbers are not too high and while knots are placed on a few thin bands, the use of this type of wood facilitates laths sawing process.

So as it was expected, and can be seen in Table 3, a large amount of knots on the diametral boards are sound knots (98%). Most of these knots correspond to the very beginning of insertion cone of branches and then the sample is not too variable. Most of its shapes (Table 4) naturally go between round and elliptical forms (70%). Only those knots placed too far from middle board appear as down knots.

Table 3 – Knots condition

data	average	std dev
% of sound knots/board	98.0	7.9
% of loose knots/board	2.0	7.9

Table 4 – Knots shape

data	average	std dev
% of round knots/board	15.6	10.0
% of elliptic knots/board	54.5	14.1
% of down knots/board	29.9	14.0

Optimising laths sawing

The main objective of this paper is to simulate the maximum profit on 30, 50, 65, 80 and 100 mm laths width (lw) sawing without sound or loose knots, in order to produce raw material to block board panels reconstruction. This is based on the principle of using radial boards in the two following presuppositions:

1. So that the constructed relationships can make sense, it's convenient to remember that the ranking of boards from each tree was considered starting from the top; this fact makes comparable the whole boards in the whole trees (three provenances, the oldest and the youngest trees and their three hierarchic statutes). Log number (ln) from 1 to 8 was considered.

2. There are two different situations where the estimation of sawn wood (in this case the amount of sawn laths for block boards reconstruction) can be obtained from an eventual maritime pinewood allotment of radial boards and what are the profit and waste using such a utilization procedure. Situations are -

- (a) in the stand, facing the trees, collecting some tree and stand current parameters and, (b) inside the sawmill, using a few simple available information (the provenance of raw material, sawing mean radial boards diameter and mean number of knot bands impressed on the boards). This data is not difficult to obtain.

The estimation of laths surface of wood sawing surface from *stand information* was intended to be done by modelling, clean wood surface and waste wood (including knotted wood and the two triangular laths sawn along the board to square it). Unfortunately the used independent variables couldn't make a good prediction of wood waste. So, it was decided to evaluate it by the difference between board surface and clean wood surface.

Board surface (**bs**) estimation model is (for stand evaluation):

Model 1 **bs** = 0.089 – 0.049 * **MNL** – 0.027 * ***m*** + 0.010 * **dbh** + 0.059 * **ln**

This model estimate less width boards in MNL stands and ***m*** trees; it does not discriminate the other forests or the other tree statutes.

Higher dbh naturally induces larger boards and the logs close to the stump increases wood profit.

Age does not estimate board surface; logs number replaces it.

This model was considered well adjusted to these data and its accuracy is about 93% (Table 5).

Table 5 - Statistics of board surface model (stand evaluation)

Model	adjusted R^2	p-level	deleted residual mean	absolute deleted residual mean
1	0.91	0	-7.23E-06	0.039

Laths surface profit (**lsp**) model is (for stand evaluation):

Model 2 **lsp** = 0.026 + 0.024 * **MNC** – 0.030 * **MNL** – 0.027 * ***m*** + 0.009 * **dbh** + 0.059 * ln – 0.001 * **lw**

This model estimates higher lath profits to MNC (it's the highest site index forest) and the lower to MNL. Estimates less wood profit to ***m*** trees (***d*** and ***D*** trees are not distinguished) and higher to largest dbh.

Logs next to the stump naturally produce bigger laths profit and shortest width of lath and lowest wood profits.

Age does not explain laths surface as well.

This model was considered rather well adjusted to these data and its accuracy is about 86% (Table 6).

Table 6 - Statistics of laths profit model (stand evaluation)

Model	adjusted R^2	p-level	deleted residual mean	absolute deleted residual mean
2	0.84	0	-6.59E-0(	0.06

Absolute values of wood wastes evaluation can be reached by the difference between the estimations of these two models.

A mean relative value of clean and waste wood laths is shown on Figure 1. The same lath width and number of logs were used as before and means dbh of 33.7 cm (MNC), 29.6 cm (MNL) and 28.2 cm (MC) were considered.

Considering both ***d*** & ***D*** and ***m*** graphics, lath profits higher than 85% were achieved only in MNC and MNL.

MNC and MNL tree higher logs present around 80% profits. Even with smallest lath width, MC forest does not achieve 70% profit.

In MNC and MNL forests 100 mm lath width can achieve profits of 60%. MC forest shows lower values; in this case, and considering 100 mm lath width, wastes will achieve more than half the amount of wood raw material (53 and 57%).

Estimation of wood laths surface (**wls**) profit *from sawmill information* was performed with the following model:

Model 3 **wls** = -0.031 + 0.013 * **MNC** + 0.016 * **MNL** + 0.025 * **db** – 0.005 * **nb** – 0.001 * **lw**

This model, that also includes the variables mean diameter of boards (db) and number of bands (nb), shows that boards from MNL promotes a little higher values of laths profit then MNC and MC (the lowest).

Concerning the influence of provenance, this model shows a little difference from model 2. Variables board mean diameter and number of knot bands perform higher and lower wood profit respectively. Higher number of bands per board naturally means low growth; so, more whorls per board and less profitable wood length between them.

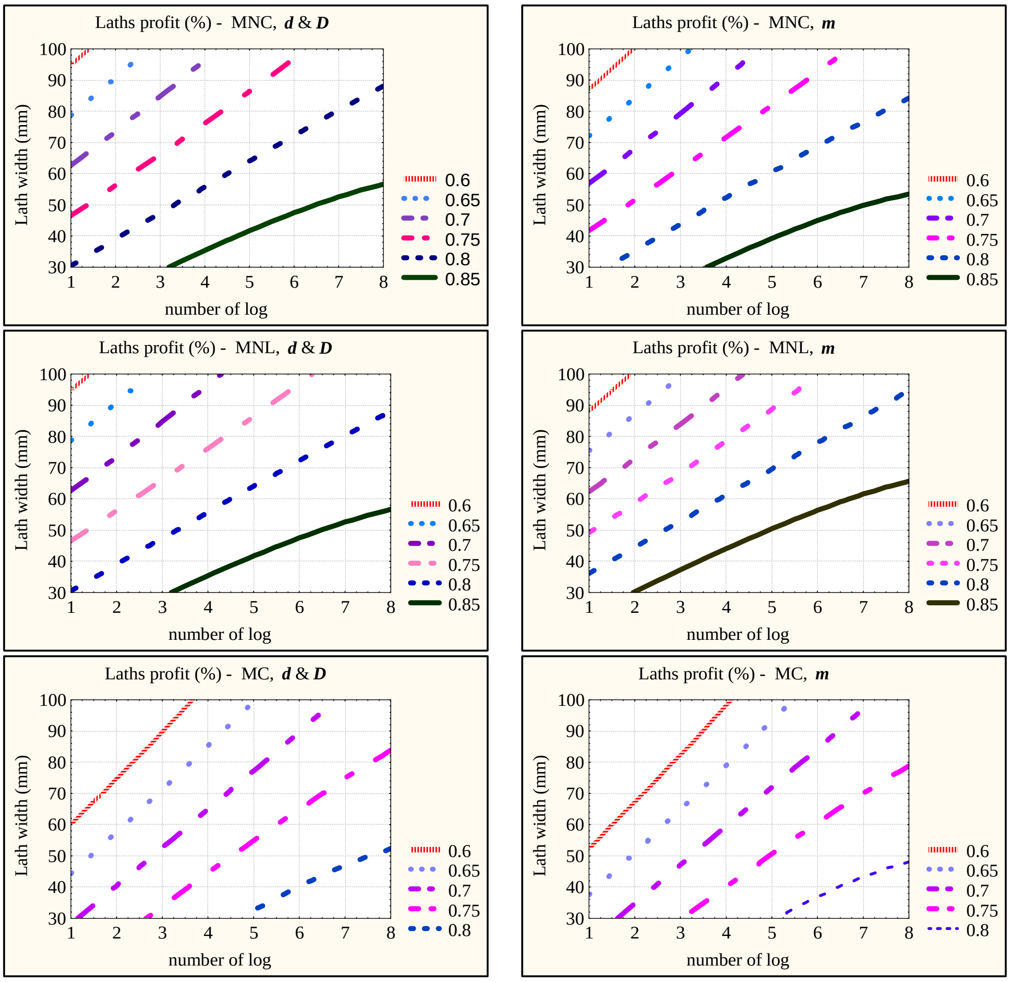

Figure 1 - Relative laths wood profit (stand evaluation)

Then larger lath corresponds to less wood profit.

This model was considered rather well adjusted to these data and its accuracy is about 89% (Table 7).

Table 7 - Statistics of laths profit model (sawmill evaluation)

Model	adjusted R^2	p-level	deleted residual mean	absolute deleted residual mean
3	0.90	0	1.75E-05	0.045

In order to evaluate absolute values of wood wastes the difference between this model estimation and one board surface must be calculated. Each forest mean diameter board (23.7 cm – MNC; 20.8 cm – MNL and 21.6 cm – MC), mean number of bands (4.6 – MNC; 6.1 – MNL and 5.3 – - MC) and board length (2.6 m) must be considered.

The relative value of clean and waste wood laths is shown in the Figure 2. Laths width and the number of logs (like before), mean diameter board and mean number of bands was considered.

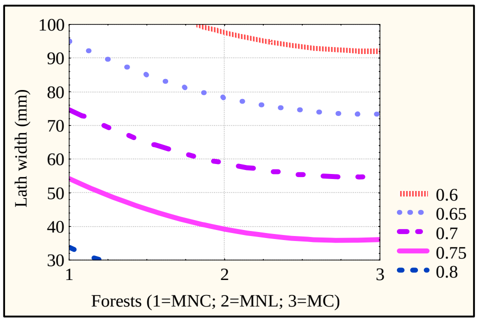

Figure 2 - Relative laths wood profit (sawmill evaluation)

This mean evaluation shows that relative laths profit of 80% is only achieved with lath width of 30 mm. It only happens at MNC. Values higher than 75% are achieved in all the forests.

Using 100 mm lath width, profits of 60% are achieved in all the forests.

Conclusions

Four main conclusions can be outstanded:

- From stand information, estimation of board surface appears different along the Portuguese littoral coast and with tree statute. It's a little smaller in the littoral centred forest and medium trees; naturally depends on the distance from top and on tree diameter.

- Stand information also estimates laths profit surface of dominated and dominant trees on the dependence on the considered forest along the littoral coast and also presents a little difference to the medium trees. Differences concerning wood profit are made by tree diameter, by the distance of log to the top and by the lath width to be considered.

- Lath profit estimation inside the sawmill also establishes differences with wood provenance; that estimation naturally depends, in a positive way, on the considered board diameter, on high tree growth by the number of whorl impressed on the board and on the lath width intended to saw.

- All the forests perform mean evaluations of more then 75% of laths wood profits with 30mm width. The size of 100 mm just performs profits of around 60%.

Acknowledgements

Authors are very grateful to the colleague Albino de Carvalho for his scientific support during the planning of data collecting. To all the colleagues from littoral forests and Forest Research Station for their support during collection and preparation of data, particularly to Dario Reimão, and to Research Project PAMAF IED 8185 for the financial support.

Submetido para publicação em Abril de 2001
Aceite para publicação em Outubro de 2001