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BEHAVIOUR EVALUATION OF THE CUTTING FORCE IN DIFFERENT THERMAL TRATMENTS OF EUCALYPTUS GRANDIS MACHINING

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Abstract. *With the development and growth of the population, happened an increase on the demand of wood, emerging the needing to plant / reforest trees, to ensure its use. Among reforestation woods, the genus Eucalyptus is largely planted in Brazil. Eucalyptus has a quickly growth but its dimensional stability and durability against biological demand are low, requiring improvements in its properties for commercial acceptance. Among other treatments used to improve wood properties, the thermal one points. The thermal treatment consists in heat the wood below its carbonization (below 280°C). Processing the wood on a final product involves some machining operations (operations with cutting tools, aiming shape, dimension and finishing to the product).This article intends to analyze the behavior of the forces acting on cutting process relating it with the variation of a thermal treatment. For this were used three groups of Eucaliptus specimens: one group with no thermal treatments, other group where the specimens were kept at constant temperature and the time of process was varied, and a third group in which specimens were kept in constant time and the temperature was varied. The results were obtained through systematic tests of machining with orthogonal cutting. The machining parameters: cutting speed, feed and depth, were kept constant in all experiments. It was observed that with low temperatures at the thermal treatment there was an increase of the cutting strengths, however, with higher temperature, there was a decrease of it. Also was observed a change at specimens colors after thermal treatment.*

Keywords: *Wood thermal treatment, Wood machining, Eucalyptus grandis*

1. INTRODUCTION

As wood have extraordinary material properties, it has been used by mankind for thousand years, and the consumption of timber continues to rise, what requests that plantation of fast grown species, like Pinus and Eucalyptus, where developed. Although, a fast growth rate results in wide growth rings, producing low-density timber that exhibits inferior mechanical properties, when compared with timber sourced from virgin forests. There is also evidences that that the durability of plantation-grown timber is often inferior to that sourced from natural-growth forests. All of the above factors result in an inferior product when compared to material obtained from virgin forests, requiring some means of upgrading the timber to achieve comparable properties (Hill, 2006). Aiming to increase the properties, some preservatives are used to prevent biological attack, however, some of this preservatives have negative impacts for environmental so starts a interest in wood modification, that represents a process that is used to improve the material properties of wood without presenting environmental hazard, and in this sense, thermal modification had shown a great solution (Hill, 2006 and Silva, 2012). And as timber suffer some machining operations, to turn on a final product, it's also interesting to observe how cutting forces behave according to the variation of the thermal treatment.

1.1 Wood

Timber is a heterogeneous organism that consists of cells arranged and organized in different directions, whose appearance varies according to the observed plane, claims Burger (1991). Intending to study, conventional cutting plans are classified, as it is shown at Fig.1. This structural difference also affects the mechanical physical behavior of wood, a phenomenon known as anisotropy, says Burger (1991).

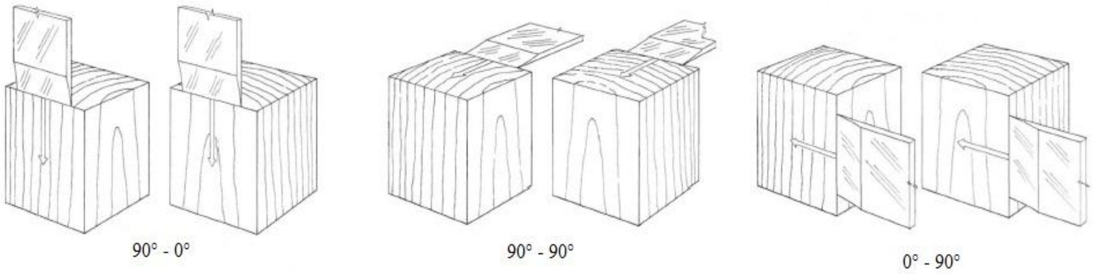

Figure 1. The three types of orthogonal cutting. Adapted from Hoadley (2000).

According to APA Engineered Wood Handbook (2002), wood is primarily composed by the basic chemical elements: Carbon (49% of dry weight), Hydrogen (6% of dry weight), Oxygen (44% of dry weight) and Others (1% of dry weight), while the organic compounds are: Cellulose (between 40 and 44%, of oven-dry weight), Hemicellulose (between 15 and 35%, of oven-dry weight) and Lignin (between 18 and 35%, of oven-dry weight).

The mentioned compounds above, according to Hill (2006) and Hoadley (2000), are characterized as follow:

- Cellulose: long-chain polymers, multiples of simpler molecules called monomers that are linked end-to-end.
- Hemicellulose: like cellulose, they are polysaccharides, but are composed of a number of different sugar units. Generally less ordered than cellulose, although some can form crystalline units.
- Lignin: highly amorphous phenolic polymer of indeterminate molecular weight. Is responsible for providing stiffness to the cell wall and also serves to bond individual cells together in the middle lamella region.

1.2 Thermal treatment

For Hill (2006), the thermal modification of wood is defined as the application of heat to wood in order to bring about a desired improvement in the performance of the material. For temperatures lower than 140°C, modification results only in slight changes in material properties, between 180°C and 260°C the thermal modification is invariably performed and above 260°C, occurs an unacceptable degradation to the substrate.

Hill (2006), still says that properties of thermally changed wood are highly dependent upon the thermal treatment employed. Those changes involves:

- improvements in dimensional stability, depending on the treatment conditions;
- reduced hygroscopicity;
- improved resistance to microbiological attack;
- often, an increase in modulus during the initial stages of heating, with a reduction thereafter;
- a reduction in impact toughness, modulus of rupture and work to fracture;
- reduced abrasion resistance;
- a tendency for cracks and splits to form, knots to come loose and so on;
- a darkening of the material.

1.3 Machining

According to Ferraresi (1995), is understood as machining, those operations whose give shape, dimensions or finishing, or any of these three items combination, to the piece, by producing a removal of material, named of chips.

Among all machining operations, the planing, which intends to obtain ruled surfaces, generated by a reciprocating rectilinear movement of the workpiece or tool, can be mentioned (Ferraresi, 1995).

During removal process, arise strengths which results on the machining force. The machining force, says Ferraresi (1995), is the total force acting on the cutting edge during machining process. It is the resultant of the active forces (cut and feed) and passive, and are considered to be acting in direction and sense of the tool, as shown in Fig. 2.

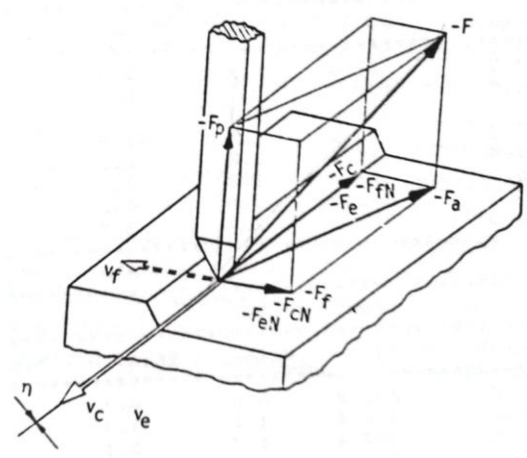

Figure 2. Machining strenghts durinf planning process. Stemmer (1995).

The knowledge of the cutting and feeding forces is critical for determining the cutting power. It is through the cutting power that is estimated the machine drive power. Since the passive force, while not contributing to the machining power is responsible for the elastic deflection of the workpiece and the tool (Diniz, 1991).

2. MATERIALS AND METHODS

For carrying out the experimental procedures, Eupalyptus grandis specimens were built, with dimensions 50 x 50 x 90 millimeters, so as to allow machining in the direction 90° -0°. Before built specimens, the plank of Eucalyptus was natural dry.

Seven specimens were used, one without heat treatment (control) and six with thermal treatment in an oven muffle mode, with a heating rate of 4°C.min-1 and without forced air circulation, as follows at Tab. 1.

Table 1. Built of specimens.

Specimen	Temperature (°C)	Time (min) (ater reaching the temperature os treatment)
1	control	control
2	120	60
3	120	120
4	160	60
5	160	120
6	200	60
7	200	120

After being thermal treated, the specimens were machined in a plane, carrying out a series of measurements in three passes at the anatomical direction of 90 ° -0 °, thus yielding the values of cutting force.

The morphological structure of the measurement system used, basically consists of a transducer (Dynamometer - Kistler model 9272), a signal amplifier (Kistler type 5070A), and a computer acquisition module A/D (model NI USB-6008) for recording data. The transducer employed is a piezoelectric one, where the signal generated by the crystal is proportional to the applied force. The acquisition rate used for recording caught signal was 1000 points.second-1. For system management, a commercial program dedicated to this purpose (LabVIEW program) was used. The experimental installation of the system is shown in Fig. 3.

Figure 3. Experimental installation of the system used during the tests.

The tests were performed in a planer whose employed parameters were: feed speed 25 m/min, feed table 2 mm/stroke and cutting depth 1,5 mm; a Titanium nitrite (TiN) parting bit with 3mm of width. At Fig. 3 can also be observed the assembly of the load cell with the specimen in the machine tool.

The files with the raw data of the tests were processed in order to obtain the cutting force curve behavior in each specimen. Each pass generated a curve, as it was given 3 passes, 3 curves per specimens were obtained. With those 3 curves, was determined a medium one for each specimens, totalizing 7 curves (for the 7 specimens).

3. RESULTS AND DICUSSION

At first, as can be seen at Fig. 4, the specimens showed variations in its colors, becoming darker over time and with the increasing of temperature during the thermal treatment.

Figure 4. Specimens after thermal treatment. Shown 1 (at left) to 7 (at right).

The changes on wood color´s occur due to the modification of hemicelluloses structure, migration of extractives to surface and formation of oxidative products. Changes in chemical compounds induce darkening of thermally modified wood (Bekhta and Niemz 2003, Esteves etal. 2008, Akyildiz et al. 2009 apud Schneid, *et al.*, 2014).

Table 2 shows data from a period of one hundredth second of test and Fig. 5 show its cutting force curve.

Table 2. Example of data from 1/100 s.

Time (seg)	Force (N)
34.941.375	86,5762
34.942.375	111,5097
34.943.375	155,2707
34.944.375	84,5408
34.945.375	84,0319
34.946.375	98,2797
34.947.375	138,4787
34.948.375	123,2132
34.949.375	81,9965
34.950.375	73,855
34.951.375	107,439

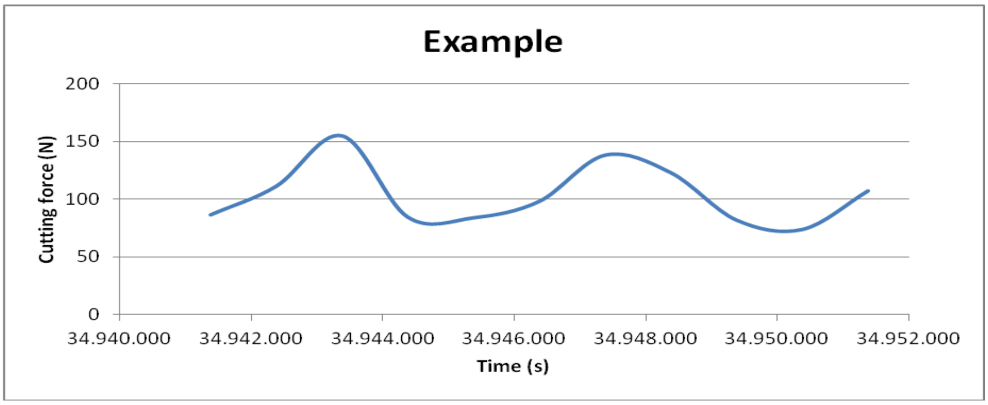

Figure 5. Behavior of cutting force in 1/100 s of test.

After organizing the files with the raw data, a graphic, as shown at “Fig. 6” was obtained.

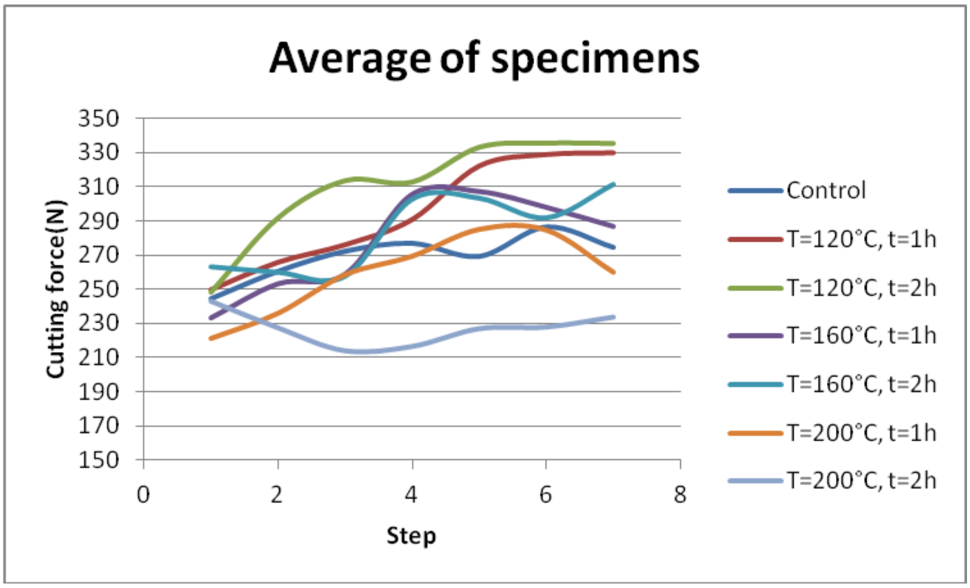

Figure 6. Average cutting force in specimens.

By a first moment specimens (as observed with specimens 2, 3, 4 and 5) showed a increase in its cutting force, showing a decrease on capacity of leaving work with cutting tool, when compared to the control specimen (specimen 1). But as the temperature get higher (as observed with specimens 6 and 7), cutting force become lower, when compared to the control specimen, showing a increase on its capacity of leaving work with cutting tool.

4. ACKNOWLEDGEMENTS

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