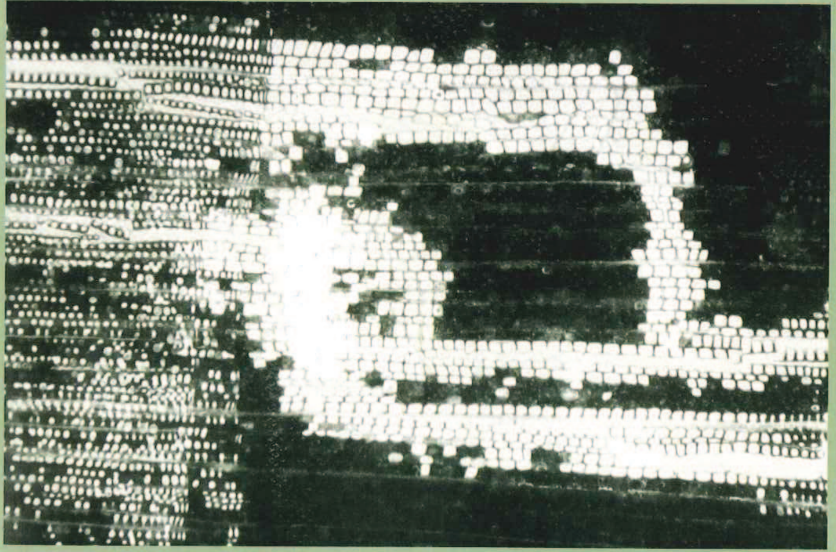
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

COST ACTION E35

Proceedings of Third International Symposium on Wood Machining

21-23 May, 2007 Lausanne (Switzerland)

Fracture Mechanics and Micromechanics of Wood
and Wood Composites with Regard to Wood Machining



Edited by P. Navi and A. Guidoum

PRESSES POLYTECHNIQUES ET UNIVERSITAIRES ROMANDES

Egalement disponible:

Comportement thermo-hydromécanique du bois
Applications technologiques et dans les structures
Parviz Navi et Frédéric Heger

Propriétés acoustiques des matériaux
Propagation des ondes planes harmoniques
Parviz Navi

Cet ouvrage est une publication des Presses polytechniques et universitaires romandes, fondation scientifique dont le but est principalement la diffusion des travaux de l'Ecole polytechnique fédérale de Lausanne et d'autres universités francophones. Le catalogue général peut être obtenu par courrier aux: Presses polytechniques et universitaires romandes, EPFL-Centre Midi, CP 119, CH-1015 Lausanne, par E-mail à ppur@epfl.ch, par téléphone au (0)21 693 41 40 ou encore par fax au (0)21 693 40 27.

www.ppur.org

Première édition 2007

ISBN 978-2-88074-725-1

Imprimé en Suisse

Chairwoman

Stefanie Tschegg, Institute of Physics and Materials Science, Vienna, Austria

Organizing Committee

Janine Imbert, Amor Guidoum, Parviz Navi, Marjan Sedighi-Gilani, Gerhard Sinn, Homeria Sunderland, Philippe Vulliemin.

Scientific Committee

A.G. Atkins (UK), L. Berglund (SE), I. Burgert (D), M. Fioravanti (IT), J. Gril (FR), A. Guidoum (CH), G. Jeronimidis (UK), S. Koponen (FI), R. Marshal (FR), P. Morlier (FR), P. Navi (CH), S.E. Stanzl-Tschegg (AT), L. Salmén (SE), H. Sunderland (CH).

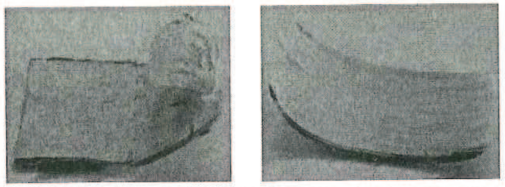


Fig. 6 TYPE I (left) and TYPE II (right) for branch machining

Franz was one of the first who studied this kind of phenomenon, then basing on this work, we could imagine this diagram (Fig. 7):

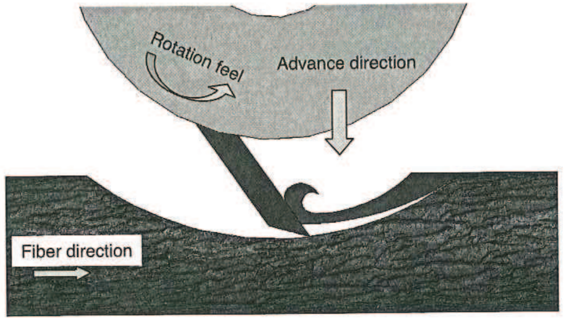


Fig. 7 TYPE I chip formation in 90-0 branch machining (adapted from FRANZ, 1958) [5]

5 CONCLUSION

In order to conclude, even if the machining is quite different from traditional wood machining, it shows to us many interesting things. The cutting mode is not a "classical 90-0" but has some similarities. For the moment, tests are at the beginning but the (Fig. 3 Causes and effects diagram of chips formation) will permit us to vary a multitude of parameters in order to find the combination which will ensure an optimum cut in term of power consumption, cut quality, use safety…

6 REFERENCES

[1] « Inventaire forestier National » web site : http://www.ifn.fr/spip/rubrique.php3?id_rubrique=35&rub=cat

[2] POINTEREAU P., 2002. Les haies, évolution du linéaire en France depuis 40 ans. SOLAGRO, Toulouse.

[3] McKENZIE W.M., 1960, Fundamental analysis of the wood cutting process, thesis of the department of wood technology, University of Michigan, Ann Arbor.

[4] E. KIVIMAA, 1950, Cutting forces in wood working, Jukaisu publication, Helsinki, 1950

[5] FRANZ, 1958, An analysis of the wood cutting process, thesis of the department of wood technology, University of Michigan, Ann Arbor.

FRICTION IN ORTHOGONAL CUTTING OF DOUGLAS FIR AT VARYING GRAIN ORIENTATIONS: MEASUREMENTS AND CONSEQUENCES.

D. Wyeth[1], G Goli[2], A. Atkins[1], G. Jeronimidis[1] and M. Fioravanti[2]

[1]School of Construction Management and Engineering, University of Reading, UK
[2]DISTAF, University of Florence, Italy

Abstract
Samples of dry Douglas fir were orthogonally cut at varying grain orientations. The forces were measured in the direction of cut and perpendicular to the direction of cut. These measured forces were then resolved to enable their components along the cutting blade and perpendicular to the blade to be established. The calculated coefficient of friction between the chip and the surface of the blade was found to vary with depth of cut and grain orientation. The blades force components from varying depths of cut at each grain orientation were plotted and a linear relationship with positive intercept was found. An interpretation of the physical meaning of the intercept is proposed, based on cutting mechanics concepts and microscopy of the "process" zone.

1 INTRODUCTION

The cutting process of any material is analysed by studying material removal, known as the chip formation process. The chip formation process encompasses many different mechanical mechanisms, including; elastic/plastic deformation, compression, separation and fracture, to name just a few. These mechanisms have been studied and it has been found that there are common trends. In wood cutting these trends led to the classification of three chip types [1], while in metal cutting three types of chip were also classified [2]. However, it is only when a chip is formed by a failure process along a shear plane that there are similarities between wood and metal cutting. For all of the chips formed, no matter in which classification they fall, the material removed is in sliding contact with the cutting face of the cutting tool and hence, friction on the tool face is an important factor in the chip formation process. Reducing the friction on the face of the tool reduces the cutting forces [3]. However, the friction process is not fully understood, and for simplicity Coulomb friction is often assumed. Finite element analysis uses several different friction models [4]. This paper looks at the tool face friction when orthogonally cutting Douglas Fir. Common trends are shown and explanations are proposed.

Table 1 Nomenclature

DOC	Depth of cut
α	Tool rake angle
μ	Coefficient of friction
Fc	Cutting force in the direction of cut.
Fn	Cutting force perpendicular to the direction of cut
S	Tool force parallel to tool rake face
N	Tool force perpendicular to rake face

2 EXPERIMENTAL PROCEEDURE

The same test apparatus as previously reported by Goli [5] was utilised. This comprised a hydraulically driven platform that was located, by means of linear bearings, on four guides. The velocity of the platform was set to 5mm/sec. The platform had the tool holder mounted on it, in which the cutting blade was clamped. Beneath the platform the sample to be cut was mounted on a Kistler load cell and was fixed into position using a clamp mechanism. The samples were pre-prepared to specific dimensions and grain orientations using a precision saw; this ensured that the samples were both parallel and had a good surface finish. The samples were tangentially cut and orientated so that the surface to be cut was the radial face, this ensured homogeneous cutting. The cut face had dimensions of 14mm wide and 20mm long. The depth of the test cut was achieved using a removable dead stop that was located on a datum face of the sample fixture. Depths of cut (DOC) of 0.1mm, 0.2mm and 0.4mm were made. For each DOC grain orientations of 0°, 30°, 60°, 90°, -90°, -60°, -30°and -0° were investigated. 90° and -90° correspond to the same sample reversed and, similarly the 0° and -0°; this was done so the mean grain orientation would be precise and a mean value of the forces could be established as the true cutting forces. For each cut the forces in the direction of cut and the forces in the normal direction to the cut were recorded using National Instruments data capture hardware. The cutting blade was a standard carbide insert. Prior to use it was inspected under the microscope to ensure that there were no defects along the cutting edge. The blade was clamped to give a tool rake angle of $\alpha = 20°$.

3 RESULTS

3.1 Measured forces.

The forces measured during the cutting process were Fc and Fn, resolving these forces gives the force along (S) and perpendicular (N) to the tool rake face.

$$S = \sin\alpha Fc + \cos\alpha Fn \quad (1)$$

$$N = \cos\alpha Fc - \sin\alpha Fn \quad (2)$$

When type II chips (shear plane) were formed, steady cutting force values were obtained, but when type I chips (splitting) were formed fluctuating cutting force values resulted. These differences were carried over to the S and N forces (Fig 2).

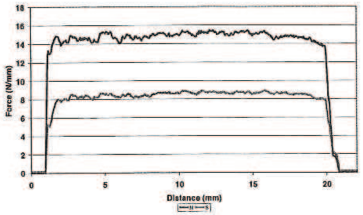


Fig 2a. Force plot for type II chip formation

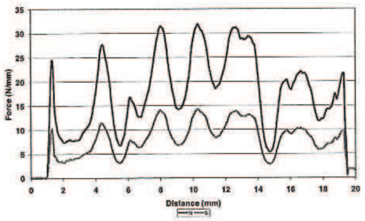


Fig 2b. Force plot for type I chip formation

3.2 Friction.

The coefficient of friction along the tool face was calculated from the tool forces (3)

$$\mu = \frac{S}{N} \quad (3)$$

Irrespective of whether Type I or II chips were formed, having stable or fluctuation loads, steady values for the coefficient of friction were obtained for each cutting scenario. This enabled a coefficient of friction value to be established for each depth of cut and all grain orientations (Fig 3)

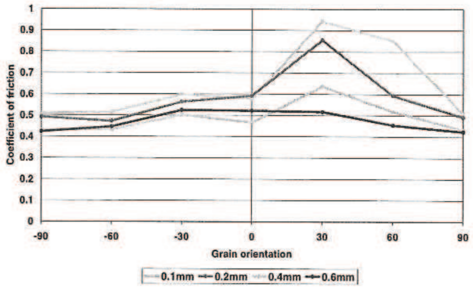


Fig 3. Coefficient of friction values for varying depths of cut at differing grain orientations.

4 DISCUSSION.

Figure 3 shows that the friction varies with grain orientation and also with respect to DOC. It was found that the coefficient of friction generally decreased with increasing DOC. The ratio S/N was plotted for varying DOC and fixed grain orientations. Linear trends were found with positive intercepts (Fig 4)

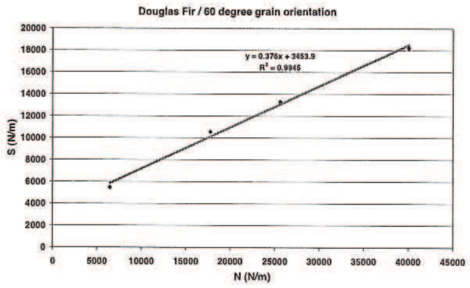


Fig. 4. Typical example of S v N plot.

If the friction were 'true' Coulomb friction the plot would pass through the origin. It is proposed that the positive intercept is due to stiction and the slope of the graph represents the true coefficient of friction (4).

$$S = \mu N + \text{Stiction} \quad (4)$$

The data in (Fig 4) using (4) would make the real μ 0.38, with a stiction value of 3500N/m. Using (3) values of friction vary from 0.45 to 0.85, depending on DOC. In a study of friction in metal cutting an adhesion/Coulomb friction model has been established [6]. The metal cutting model concluded that the chip contact length had two regions; in the first zone the chip was bonded to the tool surface and the chip moved due to shear, so the S force in this zone was equal to the shear stress of the material. In the second zone the chip slides on the tool surface and the force was due to Coulomb friction. N varied from a maximum at the tool cutting edge to zero at the end of the chip contact length (Fig. 5).

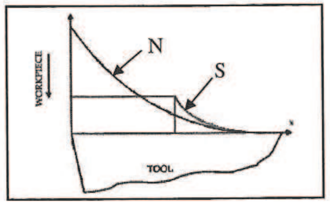


Fig. 5. Zorev's tool stress distribution

SEM images of a wood cutting tool used during subsequent high speed cutting trials showed the presence of biological material on the rake face of the blade. However light microscopy did not reveal any traces of Douglas Fir on the blade used during the slow speed cutting trials. For molecular adhesion to occur molecules have to be within a few nanometres of each other [7]. In metal cutting it is reported that the chip-rake face contact area approaches 100% [8]. It is possible that the high normal forces in wood cutting also allows for near complete contact and as such molecular adhesion.

At the low cutting velocities adhesion could occur, however the molecular bonds being weaker than the shear strength of the material, the material would move over the surface of the tool. At high cutting velocities, due to the increase in temperatures [9], it is possible for the lignin content in the wood to soften [10]. The lignin could then cause complete contact with the tool rake face and adhesion. The adhesion of the lignin-tool rake face could be higher than the reduced shear strength of the softened lignin and as such would shear, leaving traces on the tool rake face.

5 CONCLUSION.

This paper offers a theory that explains why using conventional friction theory the friction coefficient appears to vary with DOC. The introduction of a stiction zone gives a constant friction coefficient value independent of DOC. An explanation as to the adhesion process is also proposed.

6 REFERENCES

[1] Franz, N.C., An Analysis of the Wood-Cutting Process, *The University of Michigan Press*, 1958.

[2] Ernst, H., Machining of Metals, *American Society for Metals*, 1938.

[3] Paivinen, M., Heinimaa, T.,"The effects of different hand tool blade coatings on force demands when cutting wood" *International Journal of Industrial Ergonomics*,Vol 32, 2003, 139.

[4] Ozel, T.,"The influence of friction models on finite element simulations of machining" *International Journal of Machine Tools and Manufacture*,Vol 46, 2006, 518-530.

[5] Goli, G., Fioravanti, M., Sodini, N., Uzielli, L., Taglia, A.D.,"Wood Processing: a contribution to the interpretation of surface origin according to grain orientation" *IWMS 17 Proceedings, Rosenheim*,Vol (D) 26-28/08, 2005.

[6] Zorev, N.N.,"Inter-relationship between shear processes occuring along tool face and shear plane in metal cutting " *International Research in Production Engineering, ASME, New York*,Vol, 1963, 42-49.

[7] Kendall, K., Molecular Adhesion and Its Applications: The Sticky Universe, *Springer*, 2001.

[8] Trent, E.M., Metal Cutting, *Butterworth & co (publishers) Ltd.*, 1984.

[9] Garcia, R., Triboulot, M.C., Merlin, A., Deglise, X.,"Variation of the viscoelastic properties of wood as a surface finishes substrate" *Wood Science and Technology*,Vol 34, 2000, 99-107.

[10] Sheikh-Ahmad, J.Y., Bailey, J.A.,"High-temperature wear of cemented tungsten carbide tools while machining particleboard and fiberboard" *Journal of Wood Science*,Vol 45, 1999, 445-455.

STUDY OF THE WEAR BEHAVIOUR OF CARBIDE-TIPPED TOOLS UNTREATED AND CRN-TREATED IN THE FIELD OF THE BREAKING UP OF THE PINE OF ALEP

H. Aknouche [1], A. Zerizer [2], C. Nouveau [1], Y. Benlatreche [1]

[1]LaBoMaP ENSAM, France
[2]LMMC Université M'Hamed Bougarra, Algérie

Abstract
This work aims to present an experimental step related to a technique of wood machining in order to evaluate wear for the case of the breaking up of the pine of Alep.
In our case the study has been done with one untreated and one CrN-coated carbide tools by magnetron sputtering.
The deposition conditions were already optimized in previous studies [1].
The routing machine was equipped with a numerical control ***RECORDI,*** *manufactured by the Italian firm* ***SCM*** *spa and located at the ENSAM of Cluny.*

1 INTRODUCTION

The execution and the interpretation of the tests of wear were considered in various ways, since the first work of Taylor, and other experimenters. In addition, the development of new varieties of tools and the evolution of the range of machined materials, very clearly widened the operating conditions, well beyond the field of the former experiments.

So the study of wear must be approached according to a progressive and systematic step. It is thus appropriate, first of all systematically to count the multiple manifestations of wear and to observe their respective evolution, then to determine until which stage of this evolution the tool will be able to preserve qualities of cut sufficient for the good completion of the work, according to qualities required. The limits thus appreciated will then be materialized in the form of quantitative criteria, applicable to various macroscopic demonstrations of wear.

However, because same of their relative nature, it will be important to specify which of this criterion is the most restrictive one, according to the various fields of application.
It is quite obvious that, in a given field, this one only, must be retained, to judge moment validly when the tool must be withdrawn from the service for the renewal of the cutting edge [2].

Machining wood is difficult because of many factors such as differences of the physical and chemical structures between wood and metals. On the one hand, wood has a good workability leaving speed crosses high, it contains a certain water, making it very corrosive [3], on the other hand, by the weak angles of cut which can be degraded abruptly by stone remains, nails, balls of hunters.... That's why the manufacturers of tools were constrained to find a compromise between the ductility and the hardness of materials of the cutting tools.

Currently, in the wood transformation chilled steels, the high-speed steel, of satellites, carbides and the diamond of Polycrystalline (PCD) are more use; among them, most common are the face-hardened carbides, because of their good wear resistance and cost relatively low compared with the PCD [3].

Since ten years, a lot of researchers worked in this field and an improvement of the lifespan of the tools was obtained by applying nitrides, carbides and diamond-based protective coatings [1-3].

The system of Cr_xN_y produced by PVD was studied during many years by C. Nouveau *et al.* [4-5] and its effectiveness at summer proven in the field of the unwinding and breaking up of the OSB, on carbide inserts and HSS tools.

Conference's organisers

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Ecole polytechnique fédérale de lausanne

European Cooperation in the field of Scientific and Technical Research

COST ACTION E35

Fracture Mechanics and Micromechanics of Wood and Wood Composites with Regard to Wood Machining

ISBN 978-2-88074-725-1

9 782880 747251

PRESSES POLYTECHNIQUES ET UNIVERSITAIRES ROMANDES