Design of circular saw blades for quiet operation

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1- INTRODUCTION

This study presents the results of the last developments made on the reduction of the noise radiated by circular saw blades at the Acoustic and vibration group of Sherbrooke laboratory. The reduction of noise has been made on both the free running or idling noise and the cutting noise.

Our experiments showed that the free running noise is generated by the motion of teeth and gullets at high speed in the air which creates turbulences. Those turbulences can be significantly decreased as the dimensions of gullets are well chosen. The cutting noise is generated by saw blade vibrations excited by the cutting force. As the cutting force can not be easily reduced, the cutting noise has been reduced using modal analysis technics results and materials with high damping properties.

2- REDUCTION OF FREE RUNNING NOISE

The origin of the free running noise has been widely studied by several authors ([1],[2]). A tooth with an high speed motion creates turbulences phenomena in the air, the propagation of those aerodynamic disturbances which generates noise is closely dependant of gullets dimensions.

According to this hypothesis, an experimental study on free running noise versus gullets dimensions has been made using a rigid circular disk with four slots spread around the disk rim . The gullets characteristics are depth (*d*), width (*w*) and thickness (*t*). As the thickness (*t*) is equal to the saw thickness (see figure 1), a parametric study has been made varying the two other dimensions width(*w*) and depth (*d*).

According to [1], a critical ration $w/t \approx 1$ has been determinate. Under this critical value, vortex are kept inside the gullet and do not propagate, for higher values they become unsteady propagating and then generate noise.

From all those experiments and also several observations on existing saw blades, optimum dimensions for gullets have been extracted. For a 355 mm (14 inches) diameter saw blade and 3 mm (1/8 inch) thickness running at 3600 RPM, gullets should not excess the following dimensions: depth (*d*) = 9 mm and width (*w*) = 6 mm.

3- REDUCTION OF SAW BLADE VIBRATIONS

A classical approach of the problem have been applied to reduce saw blade vibrations. One of the most efficient solution to damp vibration is to use a "sandwich" structure with constrained damping layer. This solution have already been attempted by saw blade manufacturers, our experiments showed that those attempts were only efficient in soft wood, this solution had to be improved in hard-wood.

3-1 LOCATION OF THE TREATMENT

The modal behaviour of a circular saw blade has been studied for years by many authors ([3],[4]). The vibration of circular saws can be described as the sum of the motion of individual modes. The modal shapes are simply described by the loci of nodal circles and nodal diameters (see figure 2). As the saw blade is a disk clamped at its centre the maximum vibration levels are located at the free side of the structure *i.e.* at the edge of the saw blade beneath the tooth and gullets.

Our modal analysis experiments made on several saw disk showed that the modes with the highest vibrationnal levels have zero or only one nodal circle in the frequency range of interest. Moreover, those modes have from zero to a large number of nodal diameters. Hence, the vibrations to be damped are located near the edge of the saw as said above and along circles. A vibration damping treatment have to be located as close as possible to the teeth on a circular annulus (see figure 5).

3-2 CHOICE OF DAMPING TREATMENT

A software called ADNR [5] has been developed at the GAUS laboratory to calculate the sound emitted by rectangular plates with one or many layers including the effect of viscous damping. A circular saw blade is not a rectangular plate, however the software have been used to determinate the finest values of constraining layer *vs.* structure thicknesses; the damping material thickness and loss factor are given by manufacturers specifications.

Figure 3 presents the efficiency of a 310 x 310 mm composite structure *vs.* an homogenous rigid plate on the average quadratic velocity for the same dimensions and same thickness (3 mm). The reduction of peak levels is from 5 dB to more than 20 dB on all frequency range.

The great efficiency of the multi-layer plate described above can be applied to the vibration reduction of circular saw blade.

3-3 REDUCTION OF CUTTING FORCE

Based on experimental observations and intuitive considerations, the cutting force is obviously closely dependant of tooth sharpness. Experimental tests (measurement of motor electric consumption) on different type of tooth shape showed that teeth with high top bevel angle provides less cutting force than classical teeth (see figure 4).

4- APPLICATION ON A PROTOTYPE CIRCULAR SAW BLADE

An actual prototype (figure 5) has been built based on the specifications described above. The damping material and the stainless steel layer have been inserted in an annular groove in the saw body.

5- NOISE REDUCTION OF THE PROTOTYPE SAW BLADE

Lots of different circular saw blades available on the market have been tested on our fully controlled radial saw bench. Noise levels were measured in the same cutting conditions for every saw blades (feed speed = 9.96 m/min, rotation speed = 3600 RPM) at one meter from the cutting point and in front of the saw disk. These levels vary in cuting process between 90 and 98 dB(A).
The prototype circular saw has the lowest noise levels while cutting any material and free running. The average cutting noisereduction is 5 dB and a quite constant cutting noise level (under 87 dB(A)) in all type of wood.

6- CONCLUSION

The design of an actual and efficient quiet saw blade has been performed taking in account experimental and theorical studies and also using design tools (ADNR) to optimise classical but often mismatched damping solutions.
The prototype saw blade has the lowest noise levels both during cutting operations (≈ 87 dB(A)) and free running (82 dB(A)) among all circular saw blades tested at the GAUS laboratory. Those noise levels make it safely usable in workshops in an acoustical point of view. Moreover, an indirect effect of reducing vibration is the decrease of chip removing, an improvement of finishing quality and longer lasting cutting performance between resharpments.

7- ACKNOWLEDGMENTS

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8- REFERENCES

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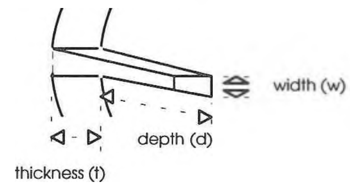

Figure 1 - Dimensions of the gullet

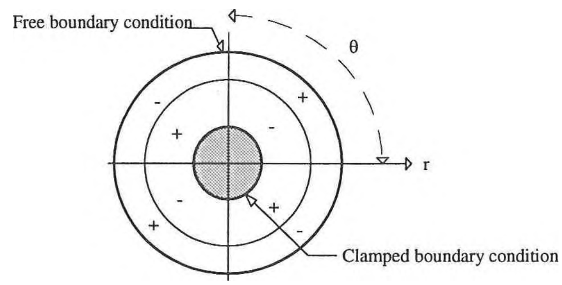

Figure 2 - Modal pattern of circular disk with 2 nodal diameters and 1 nodal circle

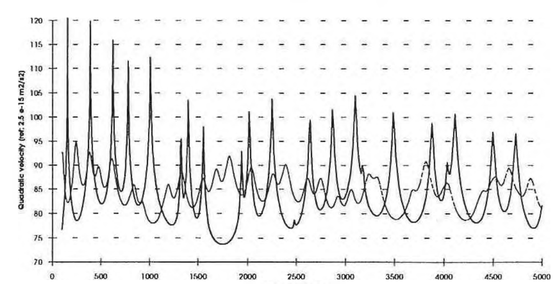

Figure 3 - Quadratic velocity of multi-layer structure (- - -) *vs.* homogenous plate (___)

Figure 4 - classical shape of alternate teeth *vs.* high top bevel angle alternate teeth

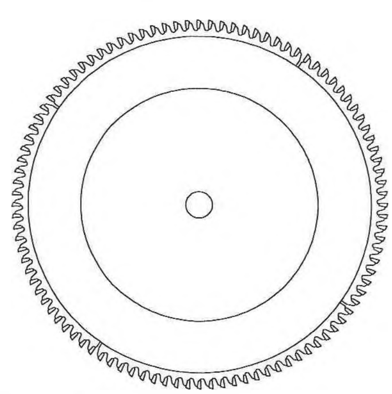

Figure 5 - general aspect of the prototype circular saw blade