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Influence of Tool Geometry on Self-feeding when Sawing Frozen Wood

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ABSTRACT

Sawing during the cold winter period is a problem for sawmills operating in the northern parts of the world and is becoming an increasingly important economic factor. One common effect of processing frozen timber is poor barking leading to increased tool wear and decreased pulp-chip quality, which implies lower chip value. Other common effects in the conversion steps of a sawmill are sawdust attached to the surface of the sawn timber (sawdust gluing), knot rupture, tool breakdown, and self-feeding, i.e. the sawblade feeds the wood to be sawn more or less independent of the feeding equipment. This study deals with the self-feeding phenomenon and how this problem can be reduced by adapting tool parameters to the properties of the frozen wood material. The results show that the amount of sapwood in the sawn timber has a great influence on the amount of self-feeding and that the effect can be reduced by adapting the rake angle of the tool to the conditions of frozen timber. A bevel at the edges of the cutting teeth reduced self-feeding forces, but increased main cutting forces.

Keywords (max. 5): wood machining, cutting forces, quality control, tool wear

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INTRODUCTION

A traditional circular sawblade for ripsawing logs and cants is normally designed so that the cutting forces will be distributed as evenly as possible on the teeth of the sawblade (Gustafsson 1980, Csanady et al. 2013). Also the diameter of the saw blade must cover the widest dimension to be cut and the rake angles of the teeth should give favorable cutting forces and cutting result. The feeding force that is needed to feed the log or cant through the saw machine, is of special interest because a too high positive feeding force (counteracting feeding into saw machine) may be problematic to achieve with the feeding rollers. A too high negative feeding force (assisting feeding into saw machine) may be problematic since the feeding rollers may slip and the workpiece will be self-fed into the saw machine and catastrophic failures may occur due to an overload situation. A formula for calculation of an approximate rake angle γ that gives nearly zero feeding force is:

$$\sin\gamma = \frac{\frac{H}{2}+f}{R}$$

where *H* is the log or cant cutting height, *f* is the vertical distance from arbor center to feeding table and *R* is the radius of the sawblade. This formula gives as result a rake angle between 10° and 30° for normal input data from Scandinavian circumstances. Problems with negative feeding forces may occur if the rake angle is chosen to be rather large e.g. from the formula above and at the same time a log or cant with a small diameter has to be handled. Winter sawing raises also a special problem during cold conditions and especially when sawing small or midsize diameter logs. Scots pine logs are more problematic to saw under such conditions compared to Norway spruce, because of the larger sapwood content in Scots pine. Sapwood contains a lot of water and frozen sapwood is very dense and can reach a density of around 1200 kg/m^3. This means that the cutting forces will be high and using a rake angle of 27-30° means that you may get a large and negative feeding force. As a result, there may be self-feeding of the workpiece and overloading and damage of the sawblade and the sawing machine, see Fig. 1 for an example of damage to sawblade.

Other factors that increase the risk of self-feeding are newly sharpened teeth and worn or badly adjusted feeding rollers. The clearance (difference between cutting width and blade thickness divided by two) is also an important factor. Normally clearance should be 0.6-0.7 mm, but for frozen timber it should be reduced to 0.4-0.5 mm.

Experience from times gone, when there were no strong feeding rollers, recommended that after re-sharpening a very small bevel at the edge of the teeth should be grinded. This bevel should reduce the rake angle just at the very edge of the teeth. If the rake angle of a cutting tooth was 30°, the bevel would reduce that to a rake angle of about 15° just at the edge. The bevel should not be larger than the average chip thickness. A size of about 0.25 mm was about the maximum and Fig. 2 shows such a bevel on a cutting tooth.

Figure 1: Teeth damage due to overload

Figure 2: Cutting edge with a bevel (left side). View towards rake face. Rake angle 30°, bevel rake angle 15°, bevel width 0.25 mm, cutting width 4.2 mm

The purpose of this paper was to study the influence of tool geometry on cutting forces, and especially the effect of a bevel, on the self-feeding forces for frozen wood. The hypothesis that a small bevel will be favorable and decrease self-feeding effect was tested.

MATERIALS AND METHODS

A single-tooth cutting-force measurement machine used and described in several papers before (e.g. Cristovao et al. 2012, Ekevad et al. 2012) was used in this study. The machine consists of a stationary single cutting tooth (Fig. 3) which is translated horizontally and cuts grooves in a single piece of wood mounted on a rotating arm, Fig. 4. Transducers measure the forces on the cutting tooth in three directions (main force, feed force and lateral force) via a computerized analysis system.

Figure 3: Cutting tool with a tooth made of hard-metal material

Figure 4: Two samples of Scots pine with grooves cut by the cutting tool shown in Fig.3

The cutting-tooth was made of hard metal produced by Sandvik Inc. and designated DH10. It was sharpened to an edge radius of about 10 µm. The cutting speed was 15 m/s, the chip thickness was 0.5 mm, the cutting width was 4.2 mm, the rake angle was 30°, the clearance angle was 10°, the rake angle of the bevel was 15°, and the bevel width was 0.15 mm, Figs. 5 and 6.

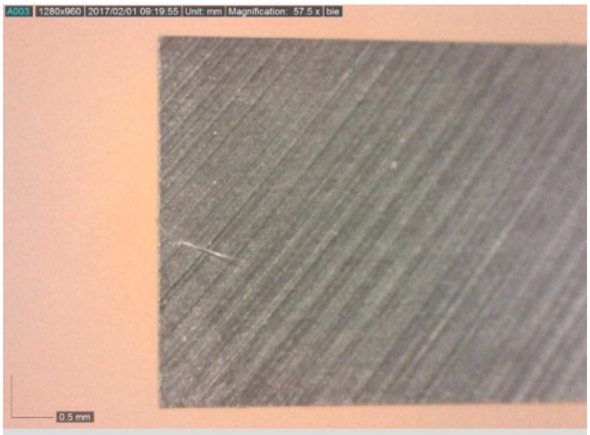

Figure 5: Cutting edge (left side) made of hard metal material DH10 without bevel. View towards rake face

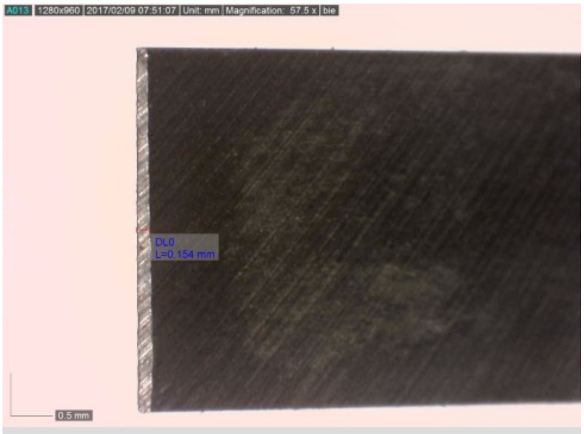

Figure 6: Cutting edge (left side) made of a hard-metal material DH10 with a bevel width of 0.15 mm. View towards rake face

Two green Scots pine (*Pinus sylvestris* L.) wood samples, denoted sample A and sample B, with dimensions of 70x70x170 mm were used. Samples were taken from the same board and chosen to be as equal in properties as possible. Sample A was used in frozen condition (temperature about -20°C) and sample B was used at a room temperature of about +20°C. The wood samples were scanned before cutting tests in a CT (computerized tomography) scanner to measure the density. Density is presented as grayscale images in Figs. 7 and 8. Absolute values of density are shown in Fig. 9. Groove number 1 to 5 was cut mainly in sapwood (high density, left half) and groove 6 to 10 was cut mainly in heartwood (low density, right half).

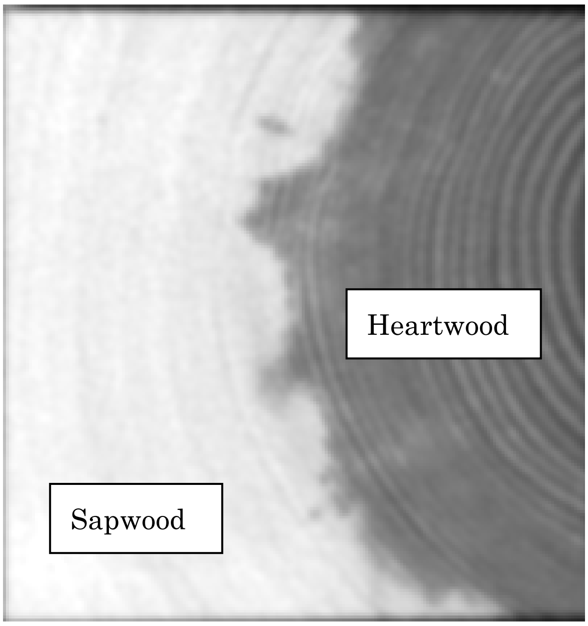

Figure 7: CT scan of sample A

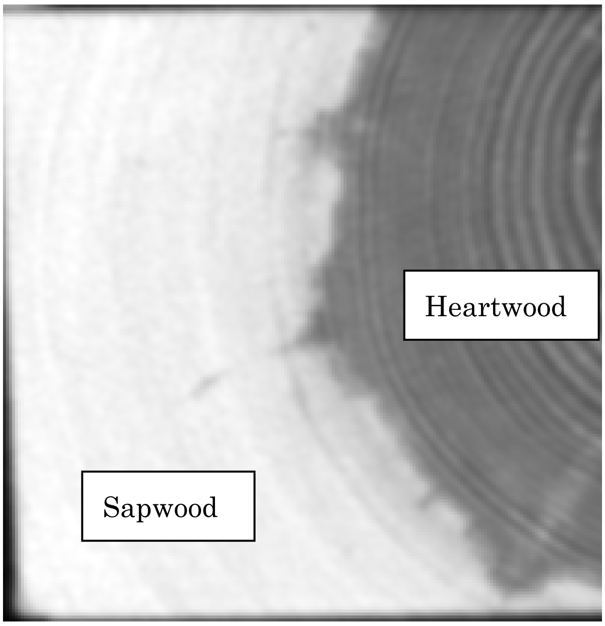

Figure 8: CT scan of sample B

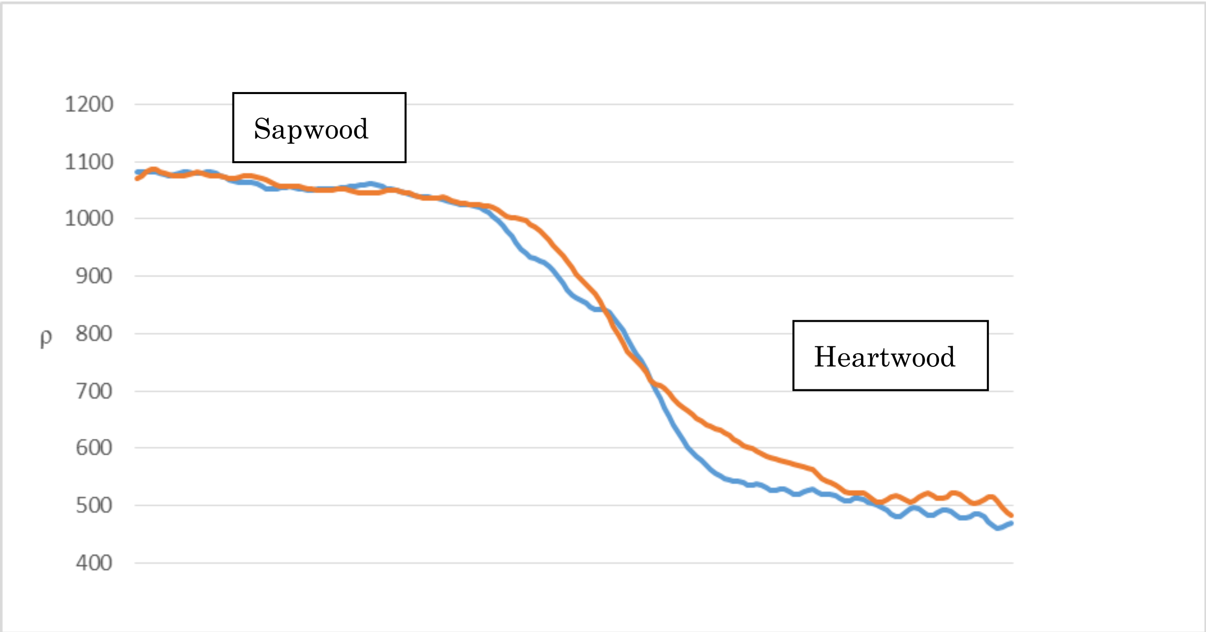

Figure 9: Mean density ρ (kg/m^3) in width direction of sample A (blue) and sample B (red).

Test sequence was as follows: First sample A at frozen condition was tested. In total ten grooves were cut to a depth of about 9 mm. Twelve cuts in each groove were cut and out of them the last 8 cuts were used for analyses. Each of these 8 cuts cut gave one value each for main, feeding and lateral force (time averaged values during each cut). Then the outer 10 mm of the sample were machined away to get rid of all of the grooves and the sample was put in the freezer again. Then the same test procedure was repeated for test sample B at room temperature. After this, the same procedure was repeated for sample A again and so on.

Both samples were tested like this three times with a cutting tooth without bevel and three times with a tooth with a bevel. In summary, cutting forces for each groove are then average values of 24 cuts.

RESULTS AND DISCUSSION

Fig. 10 shows cutting forces for sample A in frozen condition for the cutting edge without bevel and with bevel, respectively. Fig. 11 shows the same but for sample B in room temperature condition.

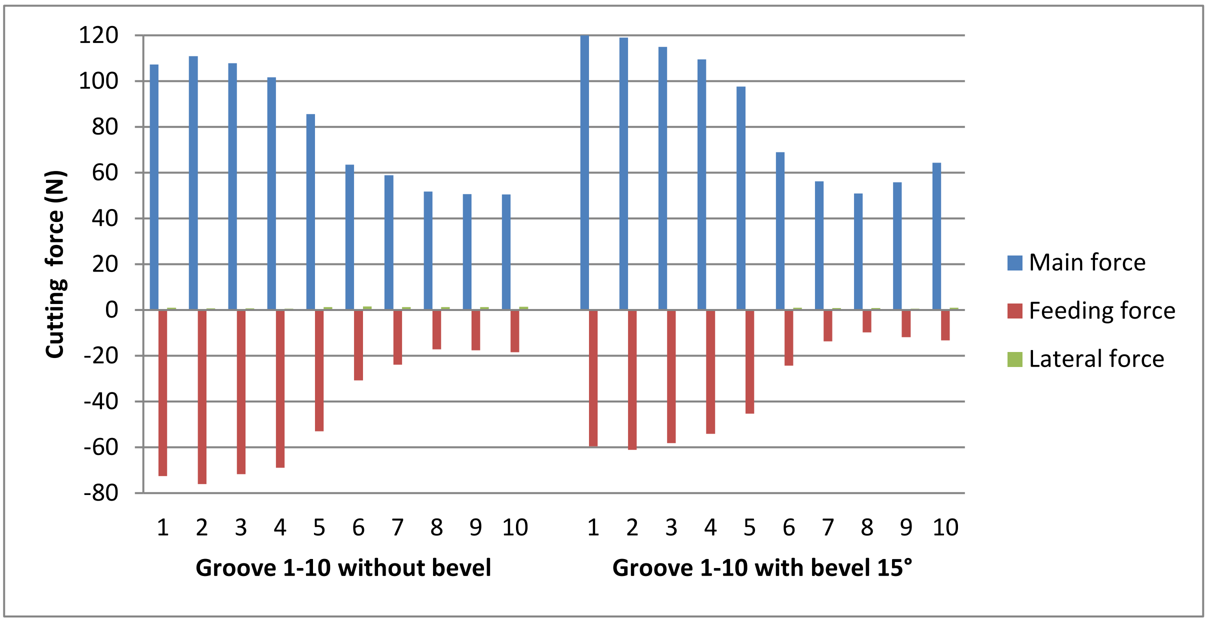

Figure 10: Cutting forces for sample A (in frozen condition)

Comparing cutting forces with and without bevel indicates that the bevel has an effect on cutting forces. The highest levels of cutting forces are the most interesting to discuss, and they appeared for groove 1 to 5 in sapwood. For sample A in groove 1 to 5 (sapwood) the effect of the bevel was that the main force increased in average 9.3%, and the absolute value of the negative feeding force decreased 19%. The lateral force was negligible, Fig. 10.

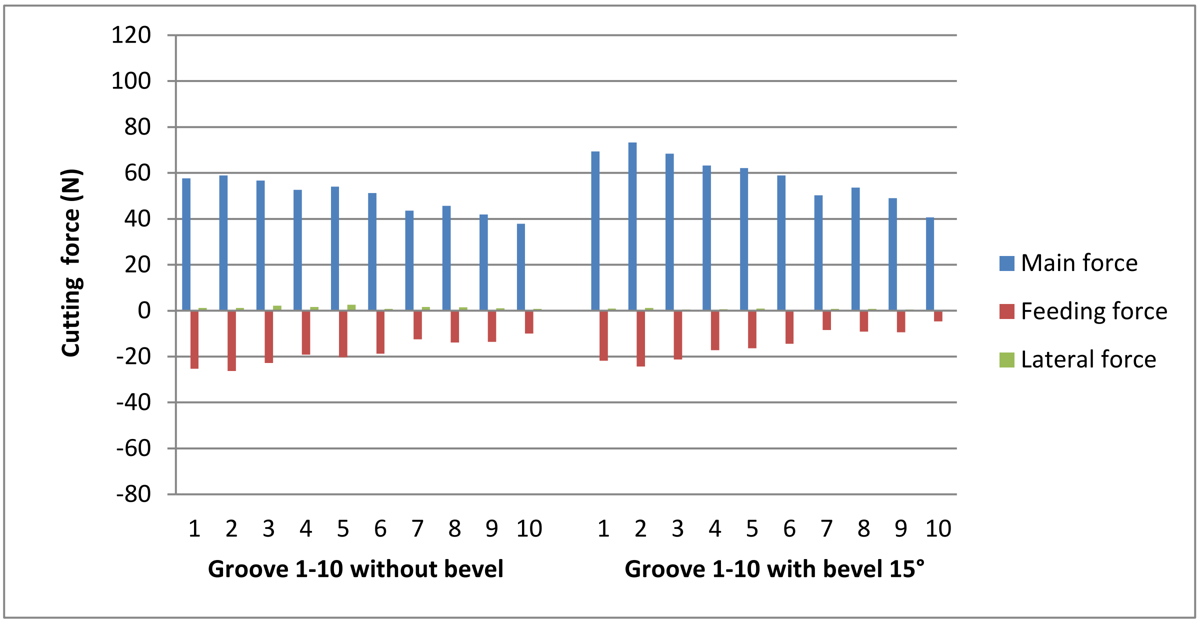

Figure 11: Cutting forces for sample B (in room temperature condition)

For sample B in groove 1 to 5 (sapwood) the effect of the bevel was that the main force increased 20%, and the absolute value of the negative feeding force decreased 11%. The lateral force was negligible, Fig. 11. The values of the cutting forces were, however, in general about half of the values for the frozen condition. Difference in % for cutting forces (both main and feeding) between sapwood and heartwood was higher for the frozen sample both with and without bevel compared to the unfrozen sample.

The standard deviations for 24 measured values for each groove are shown in Figs. 12 and 13. A high value indicates that there were large variations in the wood material in each groove. For the frozen sample, Fig. 12 shows that some grooves (groove 6 and 7) for the cutting with bevel had higher values. This indicates that the bevel can give more variations between cuts. For the unfrozen sample, there were no clear differences between results with and without bevel, Fig. 13.

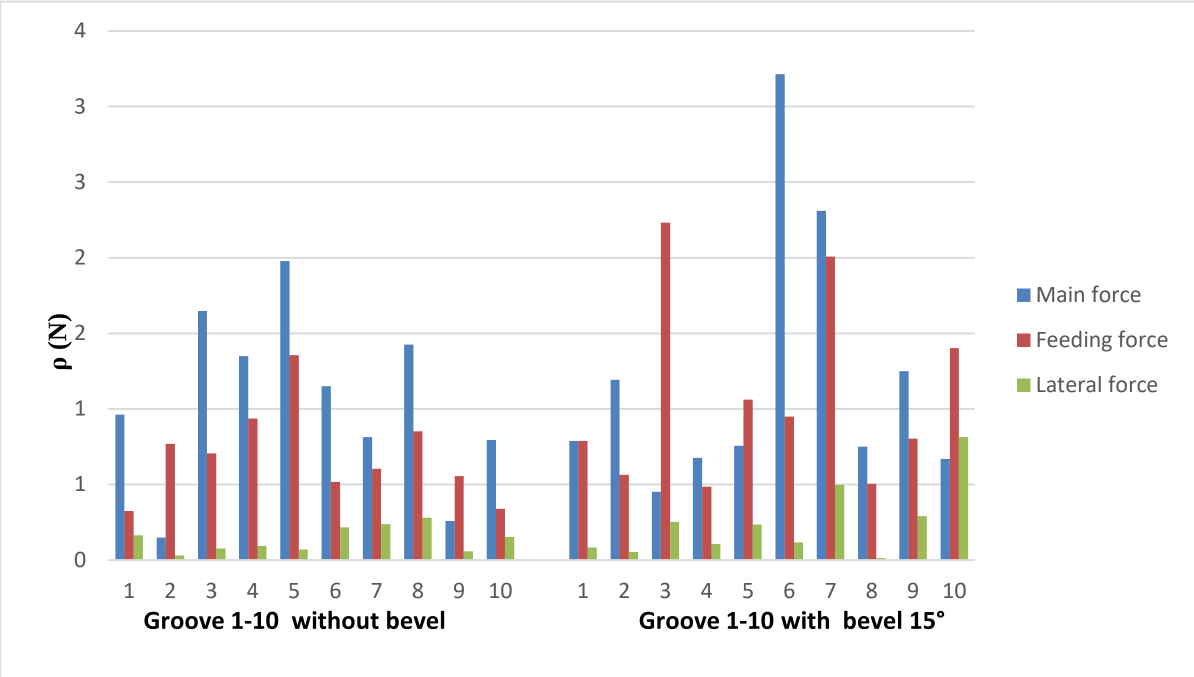

Figure 12: Standard deviation values (ρ) for sample A (in frozen condition)

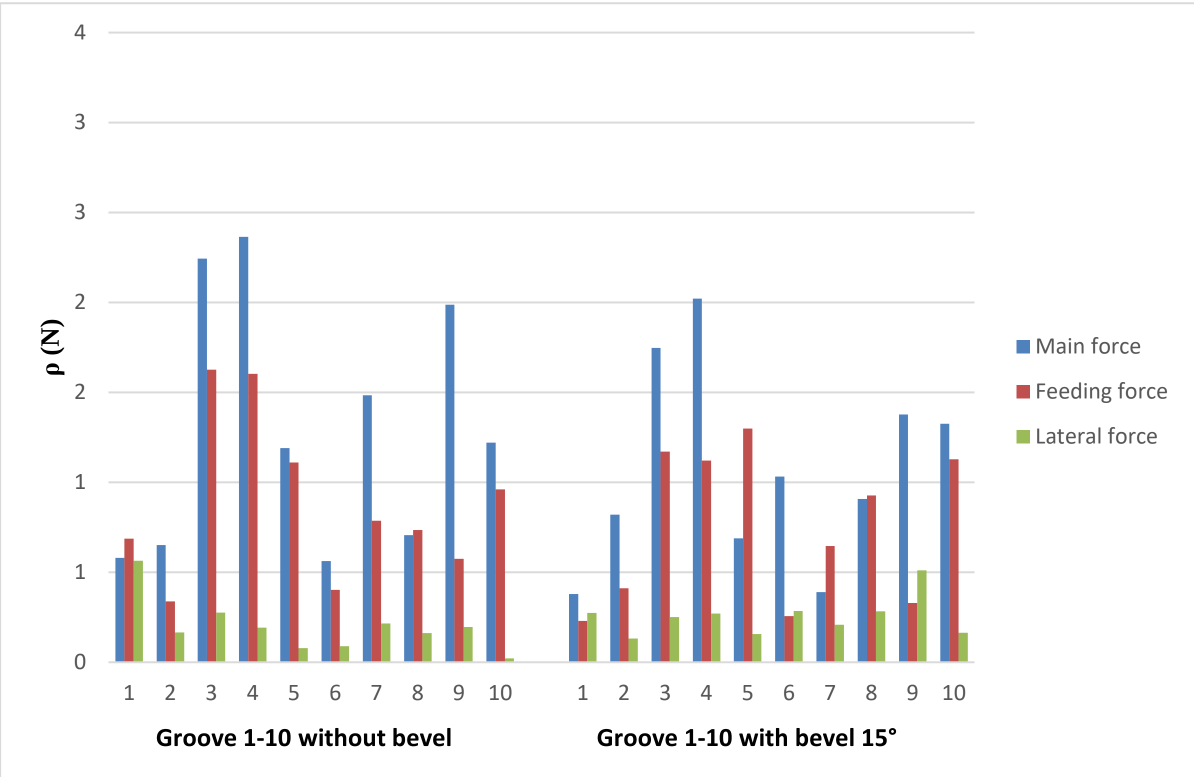

Figure 13: Standard deviation values (ρ) for sample B (at room temperature)

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CONCLUSIONS

The influence of tool geometry on cutting forces, and especially the effect of a bevel on the self-feeding forces for frozen wood was studied. Cutting frozen pine sapwood gave the largest cutting forces, both with and without bevel; in this study about double up for the main cutting force and about triple up for the absolute value of feeding force compared to cutting frozen heartwood.

There was a reduction of the self-feeding force when a bevel was introduced to the teeth, but this effect was most pronounced (in absolute values) for frozen wood. The effect was a reduction of the absolute value of the maximum self-feeding force of 19% at the most. However, also the main cutting force increased 9.3 %, which is not a favorable effect. Whether the total effect is favorable or not is an open question and answer depends on what is the main problem to deal with, self-feeding or main cutting forces.

For the unfrozen sample, the forces were generally much lower than for the frozen sample.

It would be interesting to compare effect of bevel and effect of dull edges and this is an alternative for further research.

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