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Potential for waste reduction when planing wood

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Abstract In Swedish sawmills, only half of the raw material becomes the planks and boards that is their main products. The rest turn into wood chips, saw dust and shavings. This study has investigated the potential to reduce waste simply by reducing the green target dimensions for the centre yield planks that are to be planed. It turned out that there are possibilities to reduce the green target thickness with 2.6 mm and the green target width with 3.8 mm for planks. The reduction would increase the volume yield with 0.5 % which roughly corresponds to 20,000 m^3 timber in Sweden per year.

1. Introduction

Many people visiting Sweden, and especially the northern part of the country gets struck by the abundance of forests, especially coniferous (softwood) forests. It is not surprising as less than 5 % of the total land area is populated. The majority of the country consists of productive forest land, about 57 %, with 3.0 billion m^3 standing volume of wood [1]. In addition, there are also 8 % mountains and alpine coniferous forest.

The wood is used for production of construction material, packaging, pulp, paper and energy (Figure 1). Nearly 60,000 individuals are employed in the forest industry alone and if also employees of sub-contractors are included, the number of jobs becomes nearly 200,000 which roughly correspond to 35 % of the total amount of employees in Swedish industry [2]. About 75 % of the sawn wood products are exported while the corresponding number for the pulp and paper products is close to 90 %. The export value in 2012 was 132 billion SEK which roughly corresponds to 15 billion EUR. All in all, in Sweden the forest industry really is a big deal.

Zooming in on sawmills, 46 % of the net felling volume excluding bark (68.9 million m^3) was sawlogs in 2012. In the end, the volume of sawn and planed coniferous timber was 15.9 million m^3. As sawlogs usually is shaped like a cone, while the end product most of the time is rectangular, a large amount of the

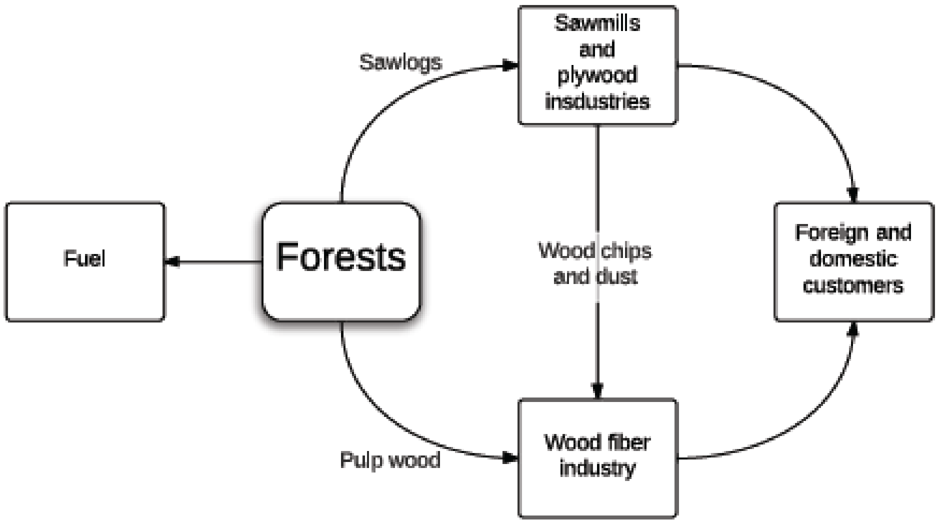

Figure 1: Schematic material flow for the Swedish forest industry.

sawlogs becomes chips and dust. The shape difference is not the only source of waste. When disjoining logs, sawmills have to take shrinkage, sawing variations, warp and planing allowance into account (Figure 2). Therefore they saw oversized planks and boards. Only 49 % of the sawlog volume turns into sawn timber while the amount that turns into wood chips, sawdust and shavings are 33 %, 12 % and 2 % respectively [3]. Also, a part of the volume is lost due to shrinkage while drying.

As the drying shrinkage of spruce planks mainly are affected by the distance from the pith [4], [5] it is possible to adjust the green target dimensions to the position in the cross-section and reduce the green target size for some of the planks and boards. Saw kerfs can be reduced by using thinner saw blades and saw teeth [6]. Also, if the sawn timber is to be planed, the green target dimension adjustment for necessary planing allowance can be improved [7]. However, so far planing optimization practically has been neglected by wood technology researchers so how much there is to gain is still an unanswered question.

A complicating factor is that the planing cutting depth is uneven along a planks face and edge; instead the cutting depth is affected by sawing variations [8] and drying distortions such as twist and crook [9]. It is those properties that give rise to planer misses, i.e. unplaned surfaces.

One of the positive effects of reducing the allowance for planing, besides less waste, is that it reduces the power consumption [10] as the required power in a

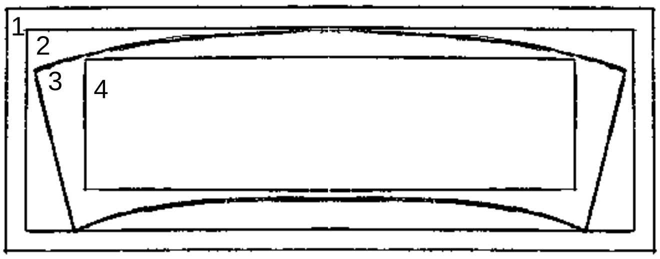

Figure 2: The green target dimension is oversized due to sawing variation (1), drying shrinkage (2) and allowance for planing (3) to finally end up as a planed plank with the sought dimensions (4).

planer is related to the amount of wood removed. Reducing the allowance for planing also increases the quality of planed goods as previous studies has found that a planing allowance over 2 mm have a negative effect on the surface smoothness [11].

If care is taken to adjust the oversizing to the logs properties, the volume yield can be improved. By careful planning, foresight and technology it is possible to decrease the waste. This study is a step on the way to do just that, and the target is to decrease unnecessary large allowance for planing.

By adjusting the average allowance for planing while optimizing the cutting depth for each individual plank, it should be possible to reduce the green target sizes while increasing the quality of planed goods by reducing the risk for planer misses. In this study, a simple reduction of the green target sizes for centre yield planks is considered. The potential for waste reduction for side boards and other sawing patterns is left for later research.

2. Material and method

For the calculations of necessary planer allowances 10 Scots pine (Pinus sylvestris) planks and 15 Norway spruce (Pica abies) planks have been used. All planks had been sawn through the pith in a conventional square sawing pattern (Figure 3). The pine planks sprung from the northern part of Sweden and had the dry target dimension 50 × 150 mm, but the average dimension was 48 × 151 mm at the time of the planing. The spruce planks that originated in the middle part of Sweden had a dry target dimension of 50 × 125 mm and the average dimension before planing was 50 × 126 mm.

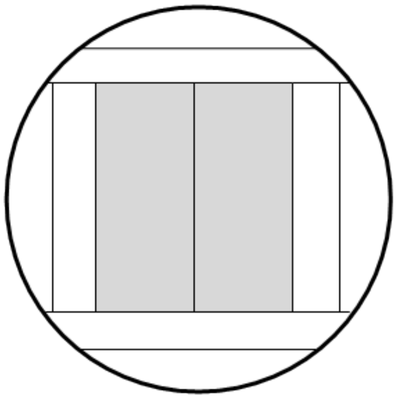

Figure 3: Square sawing pattern, the grey areas corresponds to the studied centre yield.

All of the planks were planed in dry condition (about 7 % moisture content) in the same planer at a sawmill located in the northern part of Sweden. The target dimension for the pine planks was 45 × 145 mm and the target dimension for the spruce planks was 45 × 120 mm. Even if all planks passed the requirements given by Nordic timber [12] after planing, they were randomly picketed so their drying distortion distribution should give a fair image of reality. More information about the samples can be found in [9] and [13].

In this study, the margin on one face or edge of a plank is called cutting depth, while the total margin, i.e. the cutting depth on two opposed faces or edge is called the allowance for planing.

The effective cutting depth of the planer was measured in three cross-sections of every plank, 10 cm from each end and in the middle of the planks length. The cutting depths were calculated by measuring the depth of drilled holes before and after planing (Figure 4). The measurements were made in CT images in the ImageJ software. For locations where the cutter had missed, the depth of the planer miss was estimated by extending a line from the part that had been planed and then measuring the distance between the unplaned surface and the line.

The minimum cutting depth per face and edge, cd_{min} was chosen in order to calculate the necessary cutting depth. The minimum needed cutting depth was set to 0.1 mm, so the reduction of the cutting depth, cd_{red} was calculated as:

$$cd_{red} = cd_{\min} - 0.1$$

For planks with large margins that meant that the cutting depth could be decreased. For faces or edges with planer misses that meant an increased cutting depth instead. Due to drying distortions, the minimum cutting depth on one face or edge was not located directly across the minimum cutting depth on the opposite face or edge. The result was that the total allowance for planing, i.e. the total oversize, became larger than 0.2 mm for the thickness and the width. The possible planing allowance reduction, pa_{red} was calculated by adding the cutting depth reductions from two opposing faces or edges. The necessary allowance for planing was calculated by subtracting pa_{red} from the actual dimension. As the calculations were made for dry wood, and as wood shrinks as it dries, the reduction potential had to be adjusted to correspond to the green dimensions. According [14] the shrinkage of softwood can be approximated with 0.25 % per percentage unit change in moisture content.

In order to calculate the impact of reducing the green target dimensions, sawing simulations were made with logs from the Swedish Stem Bank (SSB) [15]. The SSB consist of data from about 600 pine logs and 800 spruce logs from primarily Sweden, but it also includes some samples from France and Finland. As only the planing allowance need for the centre yield was calculated, only the logs with a top diameter between 150 and 184 mm and between 195 and 209 mm were used for the simulations as they normally would be disjoined in a sawing pattern with two centre planks. Side boards were not regarded. Two simulations were made; the first one was made with the normal green target dimensions 52.0, 104.0, 130.0 and 156.0 mm. The second simulation was made with reduced green target dimensions, i.e. the green target dimension with pa_{red} subtracted. In both simulations, the planed dimensions were 45, 95, 120 and 145 mm. The potential was defined as the difference in volume yield between the two simulations, where volume yield is calculated as the volume of the dried and planed planks divided by log volume.

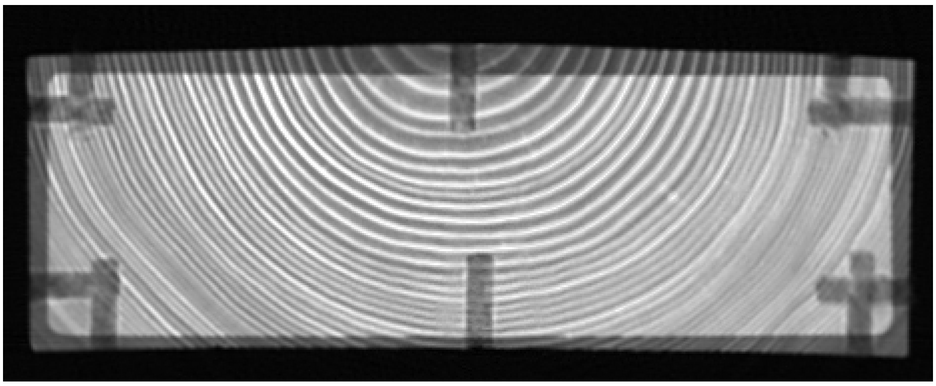

Figure 4: Example of a cross-section. The shaded area is the actual allowance for planing, i.e. material removed by the planer.

Some assumptions were made to put cubic meters in perspective. The taper of a Swedish pine or spruce is approximately 10 mm/m on average while a normal log length is 4.5 m [16]. If it is assumed that the average top diameter for a sawlog in a relevant class is 185 mm, then the butt diameter would be 230 mm. If it also is assumed that a log is a truncated cone with a circular cross-section the volume of an average log becomes 0.15 m^3. The sample tree, would have a length of about 23 m, and then the total wood volume for that tree would be about 0.32 m^3 excluding branches and bark. A reasonable estimation of the load capacity of a lorry is 45 m^3 logs without bark.

3. Results and discussion

Although the cutting depth in theory was fixed for the sapwood face and one of the edges, the actual cutting depths varied due to distortions, mainly twist and crook. The dimensions were fixed, so the cutting depth on the pith face and the other edge depended on the rough dimensions of the planks.

An allowance for planing of 4 mm, or a cutting depth of 2 mm/face, for the thickness should be sufficient to avoid planer misses. However, the average allowance for planing in the thickness direction was 6.5 mm with a standard deviation of 1.4 mm. That makes the planks 2.5 mm thicker than what was necessary. Recalculations to green target sizes give a possibility to decrease the thickness with 2.6 mm without jeopardizing the quality of the planed planks.

For the width, only a planing allowance of 2.8 mm or a cutting depth of 1.4 mm/edge is necessary. The average planing allowance was 6.4 mm with a standard deviation of 1.6 mm, so there was a potential for reducing the width with 3.6 mm while avoiding planer misses on the edges. The green target width could therefore be reduced by 3.8 mm.

According to the simulation, if the only measure to reduce waste in connection with planing was to decrease the green target dimension according to above, then the volume yield for the centre planks would increase from 30.3 % to 30.8 %. That is an average increase of 0.5 %. If it is assumed that a quarter of all sawn timber produced in Sweden is planed centre yield, then 0.5 % corresponds to almost 20,000 m^3 wood, or 60,000 spruces and pines or 130,000 coniferous logs in Sweden every year. In terms of timber loads that is more than 440 lorries of sawlogs each year.

As the measurements and calculations take planer misses into account, there is a possibility to decrease the green target dimensions and remove the risk for unnecessary planer misses if a planer/moulder could adjust the settings and cutting depth for individual planks. Unfortunately, to my knowledge no planers/moulders have the capability to adjust settings to individual planks at a normal production rate. However, a future sawmill, with a future planer/moulder, could produce planed timber with less waste and with a higher quality concerning planer misses.

A reduction of the green target dimensions could have some effects not considered in this study. One is the possibility to fit more boards into a sawing pattern and in that way further increase the yield. Another is that there could be a possibility to use thinner logs for production of the same plank dimension, or at least reduce the risk for wane for the log diameters used today.

Most of the waste produced by sawmills and planer mills is used as either raw material for the wood fibre industry or as fuel for heating and wood drying, but by directing the distribution of where the waste is produced, the handling of chips, dust and shavings could get easier and as the waste can be cleaner and more uniform the value would increase.

4. Conclusions

Given that a planer/moulder could adjust the cutting depth for individual planks:

- the green target thickness could be reduced by 2.6 mm,
- the green target width could be reduced by 3.8 mm,
- planer misses would diminish, and
- volume yield would increase by 0.5 %.

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