OnTop DOT- A case study for the non-woven industry

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Abstract

This report describes a case study of OnTop DOT, software that minimizes the overall waste in reel cutting on a paper mill. The study was conducted at a Swedish non-woven mill. The results are based on a comparison between the actual production and the solutions generated by OnTop DOT. The tests shows that DOT in all cases where able to reduce the total waste loss significantly.

Introduction

At paper mills large rolls (hereafter called reels) are cut into smaller rolls. Defects (detected by an inspection system) in a reel can cause rolls to be rejected. DOT is software that minimizes this wastage. One could almost say that DOT tries to cut around the defects.

The reader is assumed to be familiar with the terminology and other aspects of this process. A few comments may be in order. A grouping of customer orders where all the associated rolls can be cut from the same reel (same length, quality, layering…) are in this paper referred to as a *sub problem*.

This paper presents the results of a comparison between the actual waste losses in the production at a non-woven mill in Sweden with the solutions generated by DOT.

Description

The study was made on two out of three production lines (called *Line 1* and *Line 2*) for a period of one week. Only *sub problems* that had more than one roll width were studied.

- In the solutions generated by DOT no repositioning between sets were used. Due to the fact that the material stretches, knife changes between sets within a reel are avoided. This is also to our knowledge quite uncommon in ordinary paper mills (probably due to the time factor and an increased risk of errors related to knife repositioning).

- The stretch causes other difficulties in the comparison. Even though DOT can calculate with stretch the mill in question doesn't have a mathematical model for how the stretch varies across the width of the reel. Therefore DOT used a larger offset than was theoretically called for. This guarantees that the cutting patterns generated by DOT fits the reel even when stretch is involved.

- The mill in question used so called help rolls. Help rolls are used to decrease the trim loss. After they are produced they are generally put into stock for later delivery. DOT didn't use any help rolls. Would they have been used they would most certainly decrease DOT's waste loss even more. However in this case there was no call for them.

- DOT didn't use scrap rolls[1] in any of the sub problems. Usage of scrap rolls would have given lower loss.

- Only the rejections of rolls that could be linked to defects were considered in the production.

In this report we also present results from offline simulations. These simulations were conducted in the following manner. Given an optimal trim planning (generated by OnTop Trim) to a real world sub problem (in this case from the paper industry), reel and defect information (not necessary from the same mill) a reference solution was created. This was done by placing the planned cutting patterns on the reels and thereafter the additional rejection loss was calculated. We then compared this with DOT's solution to the same problem. This probably gives the best value on how much DOT decreases the waste loss since we compare with an optimal plan.

Results

The case study

In this section two sub problems will be presented one from *Line 1* and one from *Line 2*. In fact these were the only sub problems that contained more than one roll width.

All losses are presented in mm. A reels loss is the sum of all sets losses (in one dimension). If one wants to know the loss in m^2 just multiply with the set length (and 1/1000).

Sub problem I

The following table shows the roll widths and the initial demands:

Width (mm)	*Demand (rolls)*	*Comment*
180	*0*	*Help roll*
252	*1020*	
304	*1424*	
314	*1224*	
326	*616*	
334	*816*	

[1] *Scrap roll*, a small roll that are used to cut around defects.

DOT didn't use the help roll in its calculation. Figure 1 shows the mill's production compared with DOT's reel by reel. Figure 2 shows every reel's loss (trim loss [mm] + rejected rolls [mm])

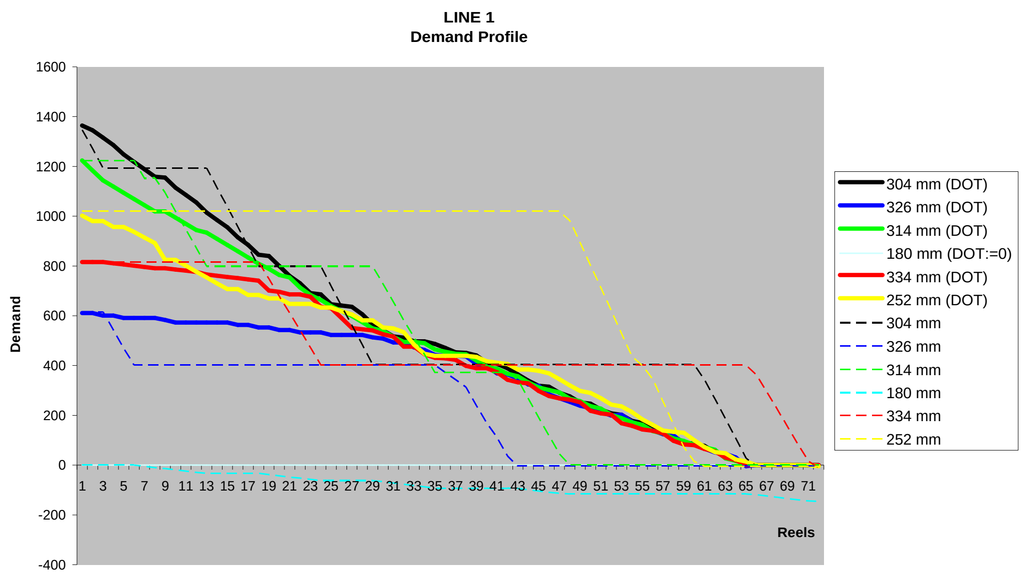

Figure 1

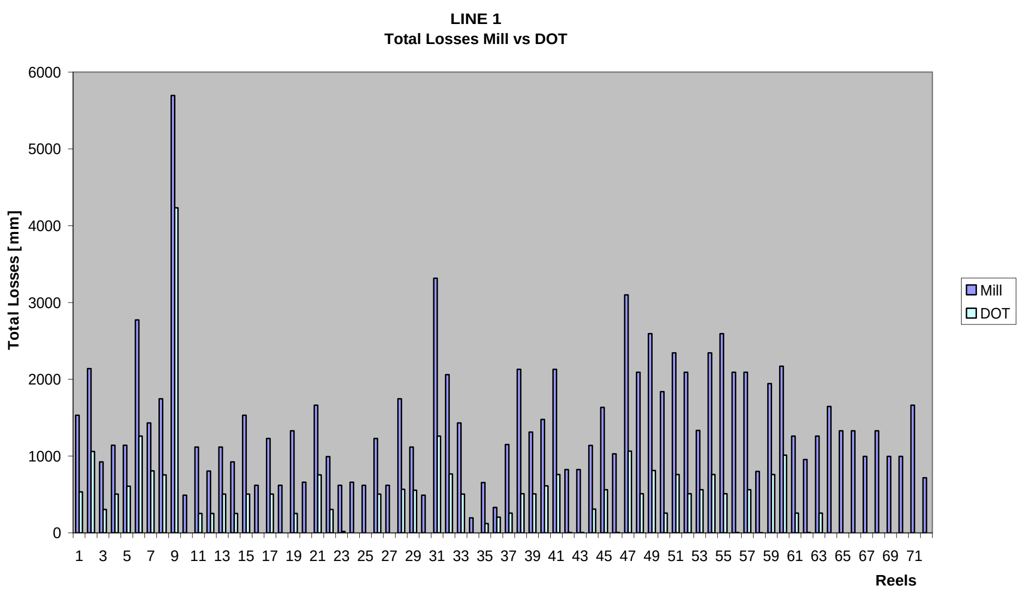

Figure 2

It's easy to see that DOT has a significantly lower loss in all reels. In this example DOT saved 70 % of the total waste loss. In fact the solution generated by DOT is *optimal up to the last reel. With optimality we mean that no better solution exists. All reels up to the last one have minimal loss.*

70% is a very high percentage, even for DOT. The main reason for this was the poor trim optimization done by the mill. The preplanned solution was non optimal and therefore had a higher trim loss to begin with.
Given the favorable situation described above a more accurate estimation for how much DOT should have saved is to compare the rejection losses. DOT then saved about 37%.

Sub problem II

The following table shows the roll widths and the initial demands for sub problem II:

Width (mm)	***Demand (rolls)***
330	*313*
250	*688*
270	*83*
375	*63*

In this case DOT saved 42% compared with the production. Figure 3 shows the demand status reel by reel and Figure 4 the two solutions total losses.

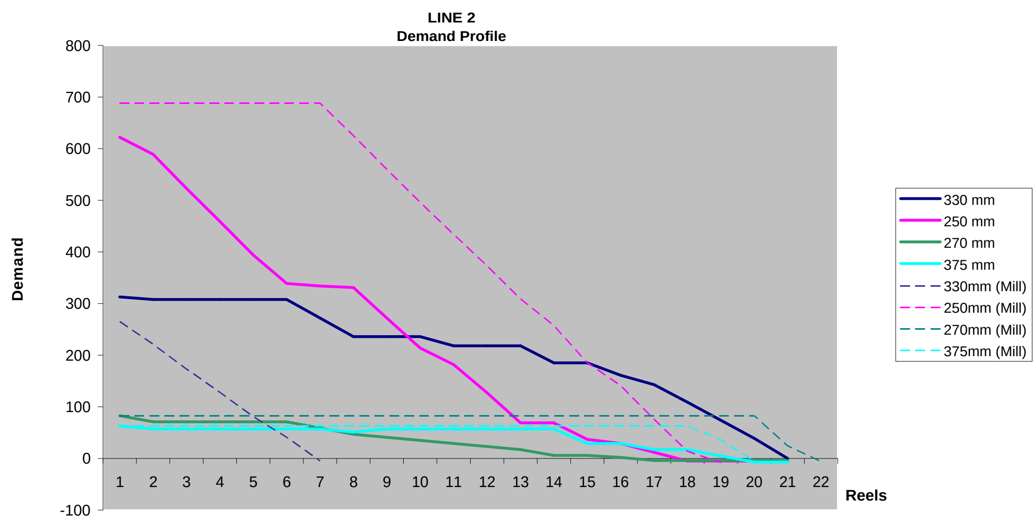

Figure 3

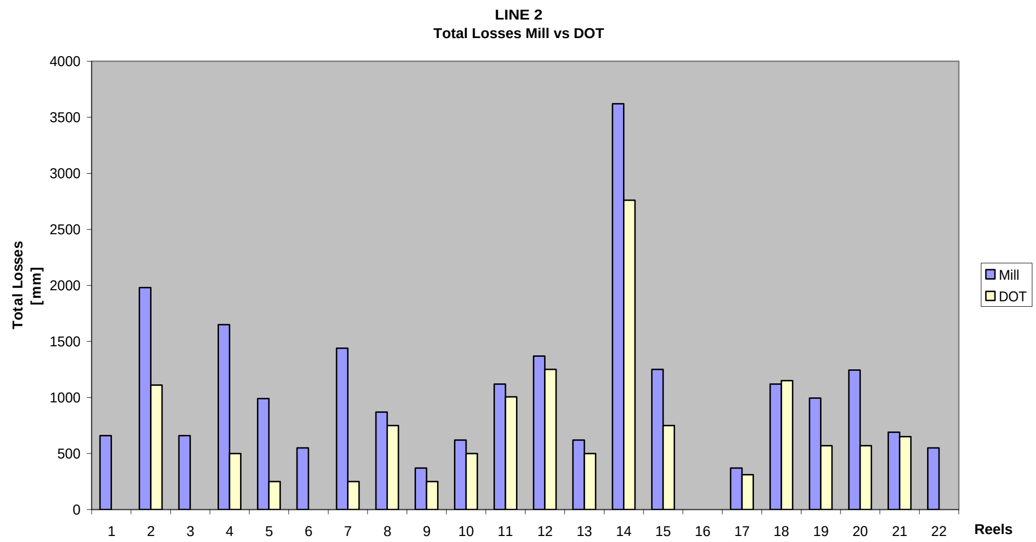

Figure 4

This solution is not optimal. In order to avoid a large overproduction of roll 270 mm in reel #16 DOT's functions for order control hade to be invoked. These functions control the usage of each roll width. In an optimal or near optimal solution one would expect the convergence from initial to zero demand to look like figure 5 or 6.

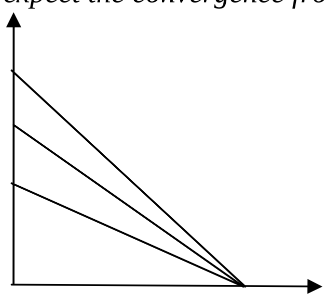

Figure 5

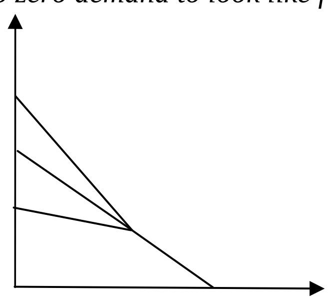

Figure 6

In fact comparing figures 5 and 6 (and the optimal solution to I) in figure 1) with figure3 shows that order control should have been used much earlier (at reel #5). This would have given an even better result. In fact DOT actually loses in one reel (#18). This is quite uncommon and is the result of our mathematical ambition to prove optimality[2].

A few comments are probably in order. The mill primarily used reels with six sets. This was probably the reason why sub problem II wasn't solved to optimality. Normally DOT would also have benefited from the fact that it has real time information and therefore can use less offset.

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[2] Optimality can only be stated if all roll widths are 'alive' (>0) until the last reel (or to its shipping date) and if all reels have minimal loss. Order control means that we may accept a slightly higher loss but with a better usage of the different roll widths.

The simulations

In this section 5 different sub problems will be presented. All of these are from the paper industry. In the table below some basic facts about the sub problems and how much DOT was able to save in each case are presented.

Sub problem	**Reel width [mm]**	**Widest roll [mm]**	**Narrowest roll [mm]**	**Number of roll widths**	**Saved loss**	**Comment**
III	5055	330	275	5	23%	Optimal
IV	4985	730	412	12	41%	
V	4985	730	250	13	56%	
VI	5450	1124	749	15	43%	
VII	4985	645	365	20	48%	Optimal

In these cases the percentage varies between 23 and 56% and it's quite easy to see how this figure depends on different factors. First of all a high number of roll widths means that DOT has more choices and therefore can decrease its waste. Furthermore the differences between the widths of the rolls are important. DOT typically uses the narrower rolls over defect areas. If the difference between widths is big this leads to solutions with significantly lower loss. The probability of rejection (or more correctly of defects) is also very important. Higher probability means greater savings.

When considering optimality and order fulfillment some other factors are involved. Here the initial demands on the different widths are important. If the wider rolls have a higher demand than the narrower rolls one must use order control. However in such situations DOT are usually able to save more since the problem is harder (see III and V) to solve. Another contributing factor is the reel length or more exactly the number of sets per reel.

Example:

Assume that we have a reel with 6 sets and that we use a roll width 6 times in the cutting pattern. This means that we're producing 36 rolls. If we instead would have used a 3 set reel. We would have ended up with 18 rolls. Longer reels therefore means lager steps in the 'demand profile' (figure 1, 3). Larger steps means that it's difficult to achieve the convergence described in figure 5 and 6. This is especially true if there are orders with a low demand.

Since DOT needs to deliver solutions between the reel-turnup and the slitting starts the computation time is important. Generally DOT solved all reels under 30 s (500 MHz Pentium). This is probably acceptable for all mills.

Conclusions and summary

Under results we have seen that DOT was able to save from 23% up to 56% (we consider the 70% in Sub Problem 1 an exception). Some of these cases were solved to optimality. This is quite remarkable since we only have information of one reel at a time. It’s also nice to know that during the production it wasn’t possible to save one single millimeter. However, aiming for optimality can easily cause some roll widths to get exhausted i.e. their demand is fulfilled, as seen in sub problem II. This usually gives a higher overall waste.

In the case study the comparisons were harder than in the pure simulations. In fact since these two sub problems had few rolls with similar widths one may conclude that the savings should be less than normal according to the discussion in the previous section.

Furthermore we didn’t use any scrap rolls in the case study. Enabling usage of these rolls would have given lower wastage. However since this mill primarily used reel with 5 sets or more and have narrow rolls DOT would rarely use this alternative. The savings would therefore have been marginal.

Appendix

Sub problem I

Below are two snapshots from the mill production and from the DOT calculations

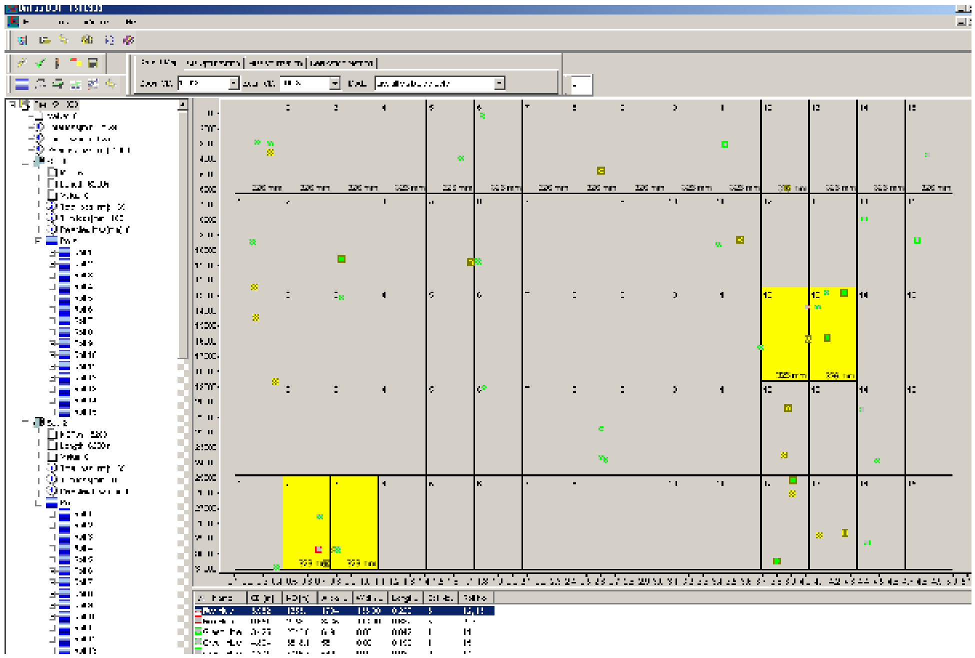

Figure 7 – Mill production

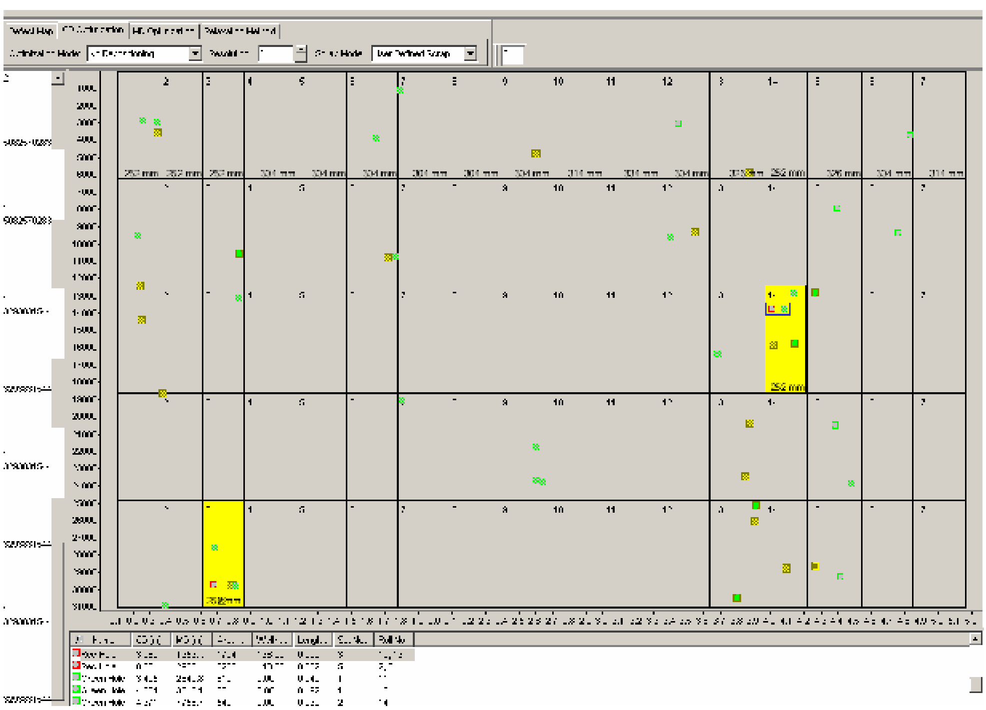

Figure 8 - DOT calculations

Sub problem II

Below are two snapshots from the mill production and from the DOT calculations:

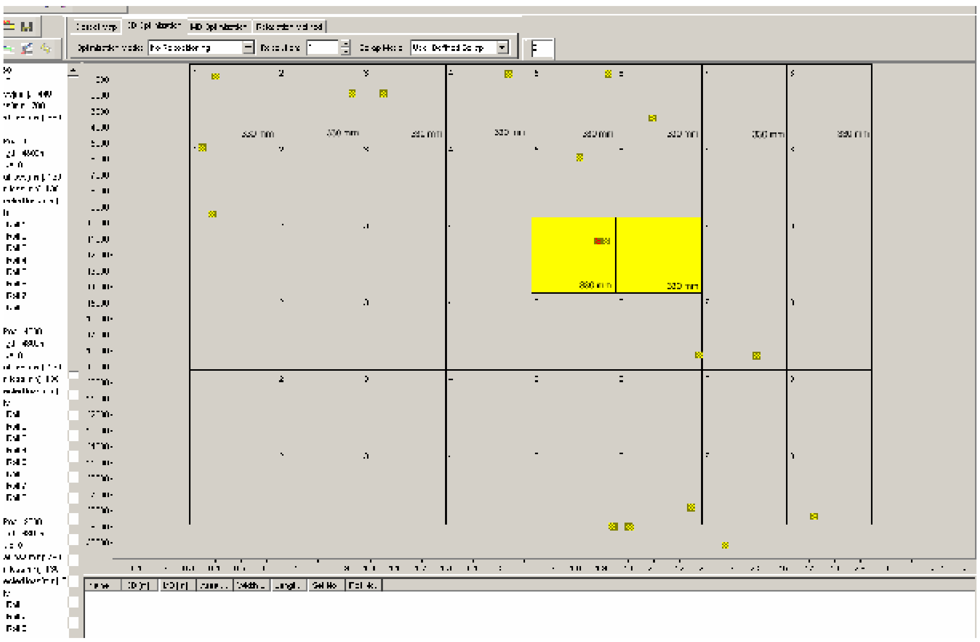

Figure 9 – Mill production

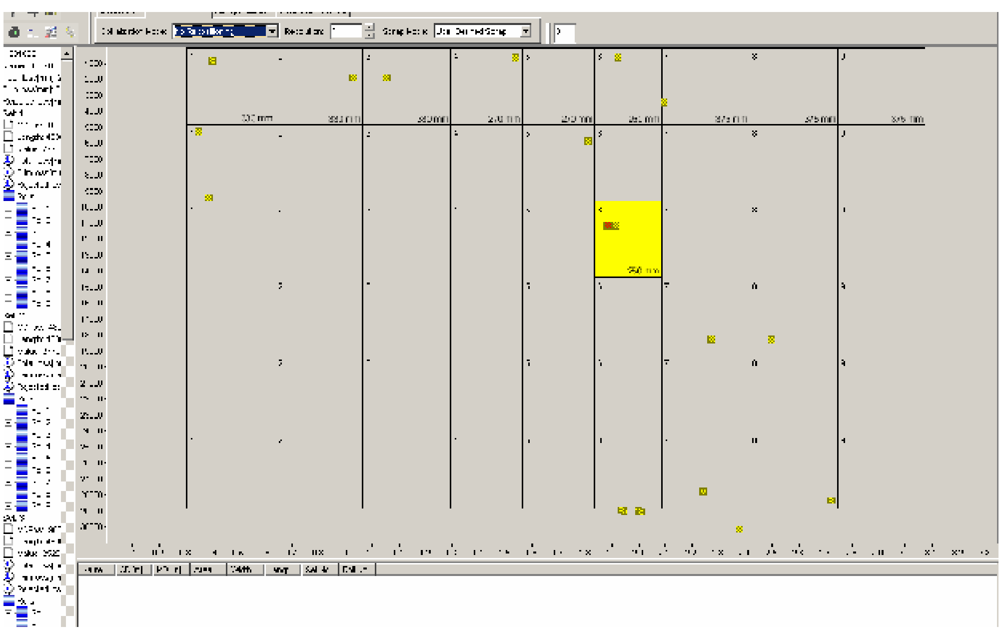

Figure 10 - DOT calculations