

# Improvement Potential in Log Rotation

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## Abstract

Several different log rotation methods are used at sawmills. They vary from manual log rotation to log rotation with a real time measurement. Furthermore, sawmills use different log rotation mechanics with different manufacturers. In general, all manufacturers have their opinions about the best log rotation technique for different sawing environments. For the best recovery, the standard deviation of the log rotation angle should be under 2° for optimal sawing, including value optimizing with tomography. The typical standard deviation value of automatic log rotation angles in sawmills varies from 10° to 15°. Therefore, there is much room for improvement in log rotation mechanics in order to get a maximal profit at this most basic and important stage of cutting logs.

If and when the log rotation is not in control, the blame is usually put on the mechanical part of the system. However, our studies have indicated that all factors from the log conveyor to the computer communication between the subsystems have an effect on successful log rotation. This article discusses the aspects of rotation mechanics which affect the log rotation precision. Moreover, different log rotation methods used at sawmills are presented. Examinations and results of this article are based on log rotation studies at several Finnish sawmills during the years 2003 – 2005.

**Key words:** log rotation, log turner, sawing, optimizing, precision, yield

## Introduction

The aim in sawing is that boards become as long and wide as possible. Therefore, it is very important that log feeders and log rotators rotate the log in the best cutting position and center it for sawing. When the log has been sawed in the best cutting position in saw number one, the cant is also in the best cutting position for chipping machine number two and resawing.

Only limited research information about log rotation precision exists. Research results about optimal log and cant orientation for sawing are often based on different simulation models. Correctness of log rotation has been investigated because log and cant orientation equipment has a significant influence on the sawing yield. It has been shown by Vesanen (2005) that the value yield increase through more precise log rotation in a primary saw machine is approximately € 3 per sawn cubic metre of lumber.

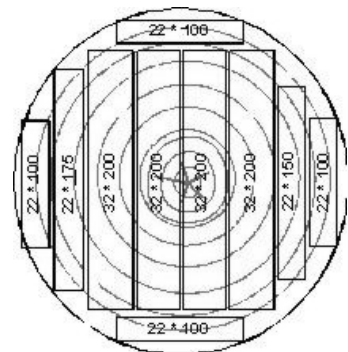
## Methods of log rotation

Five different methods of log rotation are used at sawmills. A traditional log rotation method is so-called *manual log rotation*. In manual log rotation, the saw operator rotates the log to its best cutting position visually with a system for log rotation on the sawing line. The accuracy and precision of manual log rotation has been measured by comparing the sawyer's

optimized sawing position (often sweep up) to the logs' best position defined in the log yard.

*Automatic log rotation* is based on a three-dimensional image that is constituted with an optical measurement. The image is usually rotated virtually at 5° intervals in a computer and the dimensions of boards that have been constituted for the log are investigated in every alignment of the log, Figure 1. The strength of the best result determines the rotation angle of the log. After that, the log feeder and the log rotator center and rotate the log in the best cutting position according to the rotation angle determined by optimization. This is the most frequently used log rotation method at sawmills.

The third method of log rotation is a *combination of manual and automatic rotation* in which the sawyer can fix the alignment of the log with manual rotation after automatic rotation before sawing. One



**Figure 1.** Automatic optimization of primary breakdown fits the defined products in a profile model of a scanned log and employs a logical sequence of product fitting to evaluate all possible solutions at machine allowed positions

study demonstrated that although the automatic log rotator rotated the log according to the log scaler, the sawyer rotated the log 20 degrees after the automatic rotation. Now it can be debated which one is right, a log measuring system or a sawyer.

The fourth method of log rotation is an automatic rotation that is based on *two log measuring systems*. The first measuring system measures the profile of the log and sends the rotation command to the log rotator. Then the log rotator rotates the log. The second system measures the profile of the cant after primary breakdown and calculates the profile of the cant for optimal sawing. The aim of the second measuring system is that it detects a potential systematic rotation error based on for example the twenty last measured logs, calculates a correction angle and sends the correction angle to the first measuring system. The first measuring system notices the correction angle when it is deciding the rotation angle of the next log.

The fifth log rotation method is based on log rotation with a *real time in-line measurement*. The log measuring and rotation happen simultaneously until the log is in the right position for sawing.

#### Log rotation mechanics

The logs are rotated and centered for maximal raw material usage and thus the best economic yield for the sawmill. Irrespective of the log rotation method, sawmills use different log rotation mechanics with different manufacturers. In general, all manufacturers have their opinions about the best log rotation technique for different sawing environments.

The proper operation of the rotator is vital in keeping the standard deviation of the rotation error angle small. If the log rotation is not controlled, the holding of the log slips, the angles of the tilt rolls are incorrect, rotation starts or ends when the log is not being held between the rolls or there is excessive clearance in the mechanics, there will be some error in the rotation. Careful maintenance of the system and a sufficiently robust rotator have a significant positive impact on the lumber recovery.

In *Tilt roll log rotators*, Figure 2, with one or two pairs of rolls, the rotation of the servo-controlled tilt rolls makes the log rotate when they tilt simultaneously, Figure 3. The rotation result depends on the stroke and its timing. In some applications, the rotation distance in the feed direction is constant, which makes the rotation more controlled. The rotation of the rolls is based on log scaler optimization. When the rolls are tilted, the log rotates. In the rotation, the rolls can be tilted e.g. 7.5° or 15°. When the rolls on one side tilt one way, those on the other side simultaneously tilt in the opposite direction. Logs can be rotated from the

feed direction both clockwise and counter-clockwise. The rotation direction depends on which way the rolls are turned.



Figure 2. Tilt roll log rotator with two pairs of tilts (Heinola Sawmill Machinery)

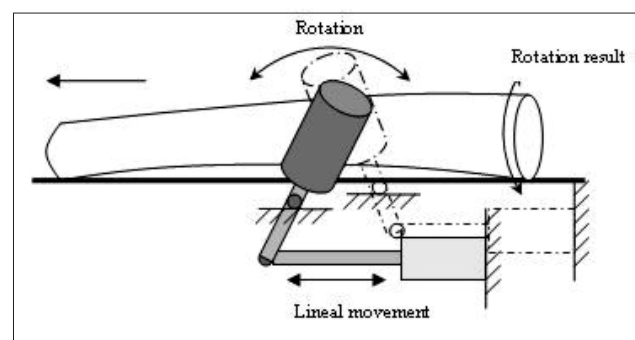


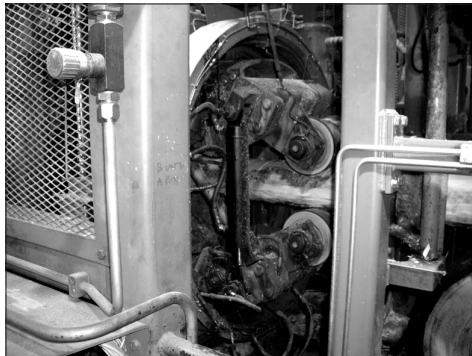
Figure 3. Transforming a servo controlled linear movement into rotation of a log (Vesanen 2005)

In the *Vertical log rotator*, two or four cylinder-shaped rolls pull the log, Figure 4. When the rolls come into contact with the log, the rolls on opposite sides of the log move in opposite directions on the vertical axis. This allows the log to rotate the desired degree. The rotation result depends on the stroke and its timing. The rolls are rotated with gear motors and both rolls have their own motor. The rolls move on hydraulic servo cylinders. The rolls rotate vertically along tracks with a round cross-section. The rotation direction depends on which way the rolls are rotated.



Figure 4. Vertical log rotator (Comact)

*Rotor log rotators* are used in both log and cant rotation, Figure 5. A rotor rotator has a ring framework on the slide bearing, which is rotated with servo controlled actuators. There may be one pair of actuators or three. The newest rotor rotators even have a two-ring framework on the slide bearing. The first ring often makes all the rotation when the second ring controls the log correctly to the saw. If the rotation angle is more than  $90^\circ$ , the second ring can be used for continuing and finalizing the rotation.



**Figure 5.** Rotor log rotator with one ring (HewSaw)

*Automatic Log Rotator with Real Time Measuring and Optimization* technology is presented in Figure 6. Its advantage over competing systems is in its real time measuring and positioning system. The log remains inside the measuring area throughout the log rotation phase, allowing accurate measurement and rotation.



**Figure 6.** Automatic log rotator with real time measuring and optimization (Genera)

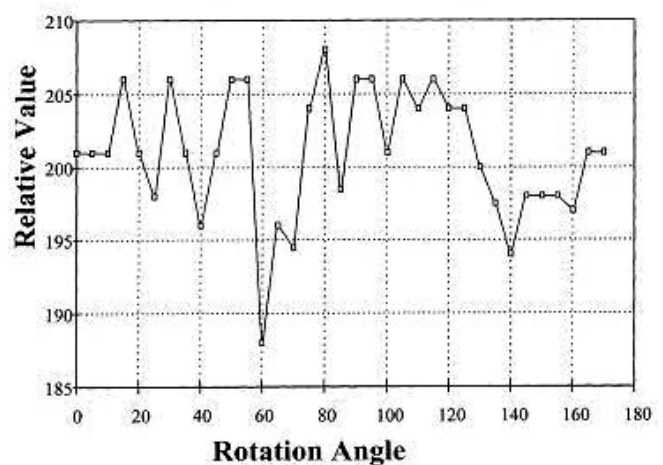
The logs are fed sideways on a conveyor having four sets of cushioned supporting legs. When a log arrives at the measuring area, it is measured and rotated simultaneously until the most favourable position is found. The log advances 1 to 2 metres during the positioning phase. At the same time, the log's travel on the conveyor is accelerated until the desired dis-

tance to the preceding log is reached (nil, unless the saw requires a certain distance) and is then locked in the correct position on the conveyor feeding the sawing unit. The automatic log rotator measures the optimal sawing position for a log based on the deviations of the x and y coordinates in the log's centre line from the virtual straight line depicting the centre line at the end of each rotation analysis interval.

### Materials and methods

The correct rotation with softwood can be "sweep up" for the log position that yields the best solution. The required rotation precision (standard deviation around the average) by experts is often stated as better than  $5^\circ$ . Usenius (2002) recommends that the precision should be better than  $2^\circ$  for optimal sawing including value optimizing with tomography, Figure 7. A larger deviation quickly leads to reduced volume and value recovery in sawing. Studies have shown that currently the best log rotators can achieve a deviation of  $4^\circ$ . The typical deviation value for automatic log rotators at sawmills is 10 -  $15^\circ$ .

### Value Yield as a Function of Log's Rotation Angle

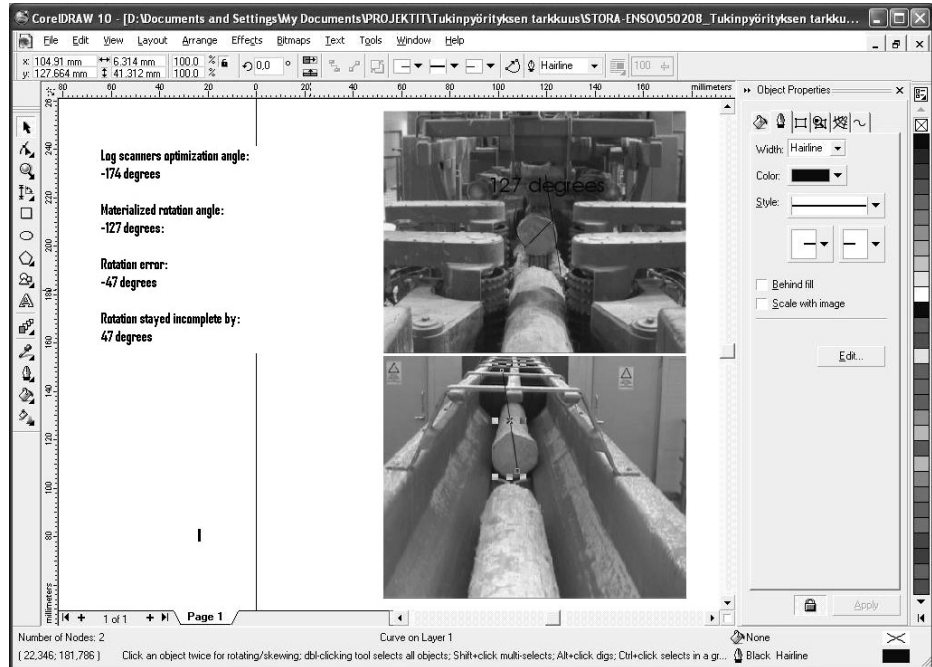


**Figure 7.** The effect of the rotation angle on the relative value yield in multi-sweep logs (Usenius 2002)

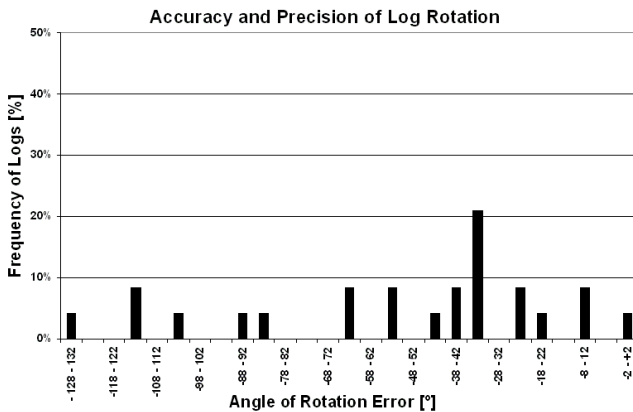
The easiest way to measure the correctness of log rotation is to record the optimization command angle from the log scanner, to digitally video record the rotation process and to measure the materialized difference between these two. Video image processing software is used to clip still photos for each log before and after rotation. The still photos are set on the same photo-editing template and the editing software is used to calculate the angle between log's initial position in

scanner and its position after rotation, Figure 8. Charts with the measured, materialized angles of difference relative to the optimization command angles are surprisingly informative, Figure 9.

ful automatic log rotation, one compares the log rotation command from the optimizer with the materialized rotation angel after rotation. The difference between the optimized rotation angle and the materialized an-



**Figure 8.** The analyzing of materialized rotation angle: The optimized angle value by log measuring system was  $-174^\circ$ . The materialized rotation angle by calculated from still photos was  $-127^\circ$ . The rotation error  $^\circ$  for a log was  $-47^\circ$ . The rotation stayed incomplete from the target angle by  $47^\circ$



**Figure 9.** The abnormal distribution of rotation errors indicates some fundamental element disturbing the rotation process. In this case the sequence of the holding rolls and the rotation of the ring were not synchronous. Sometimes the ring rotated actively, but the logs did not rotate accordingly because the rolls did not hold them

The processes belonging to production of lumber as the log rotation are dominated by normal distribution that is also called Gaussian distribution. Normal distribution in a process means that the process has an average and the individual results are distributed around the average. When defining success-

gle gives us the rotation error ( $\Delta$ ) for an individual log. For a group of logs we will get the features which describe the behavior of the whole sample, such as the log rotation error average ( $\bar{X}$ ) and the standard deviation of the rotation angle ( $s$ ) around the rotation error mean. Table 1 shows a log rotation summary on one log rotation study.

**Table 1.** Log rotation summary at one sawmill. The average deviates significantly from  $0^\circ$ , and the standard deviation is large

LOG ROTATOR TYPE:	Double tilt roll	LINESPEED (m / min):	100
LOG DIA (mm):	277	LOG LENGHT (m):	4 to 6
SET-UP (mm by mm by pcs):	Heartwood 32 x 225 x 4; Boards 32 x 150 x 2		
Log number	Rotation angle [°]		
	Optimized by log scanner	Materialized by calculation	Materialized-Optimized Rotation error $\Delta$ [under (-) / over (+)]
1	-91	-45	-39
2	93	64	-53
3	-175	-122	-34
..	..	..	..
..	..	..	..
173	-153	-106	-47
174	-54	-31	-23
175	73	60	-13
<b>The average Rotation Error [°]</b>			<b>-23.6</b>
<b>Std. Deviation of Log Rotation Angle [°]</b>			<b>14.9</b>

The average rotation error describes the accuracy of the process on average. When the average is zero or near to it, the process is accurate on average. The deviation describes the precision of the system. The deviation of the rotation angle describes the width of the distribution of measured rotations. In other words, a deviation describes exactly how the process is "in a cluster". When the deviation is small, the log rotation process is in control. Again, when the deviation is great, the rotation process is not in control.

However, the analysis of log rotation success should not be limited to the features  $\bar{X}$  and  $s$ . It is of interest to examine how many of the rotations hit an acceptable range. We will define the acceptable range as an area in which the  $\Delta$  is small enough, such as  $(-10^\circ = \Delta = +10^\circ)$ . This means that the materialized rotation deviates less than  $10^\circ$  from the target value, e.g. the standard deviation is  $3.3^\circ$  with the confidence level  $Z$  of 3. The allowed deviation from the target value and the number of logs that must hit the target range are matters which each sawmill must decide individually.

## Results

### *Log rotation methods*

In *manual log rotation* the average rotation error varied from  $-3.7^\circ$  to  $1.3^\circ$ . So, the log rotation succeeded quite well on average. Nevertheless, the standard deviation of the rotation angle (around the rotation error mean) varied from  $29.1^\circ$  to  $35.3^\circ$ . The most significant complication when determining the accuracy and precision of manual log rotation was that logs in the log yard had bark, whereas on the sawing line they had been debarked. Further, the log shape and direction of the sweep might seem different in the log yard and on the sawing line. In addition, the sawyer might take into consideration the places of knots on the log's surface when deciding the sawing position. Also straight and smooth logs could make the sawyer's optimization difficult: from the yield point of view, there is no big difference between the different sawing positions in which these logs are sawn. Hence the manual log rotation method is not supposedly as poor as the high standard deviation values demonstrate.

In *automatic log rotation* the average rotation error varied from  $-23.6^\circ$  to  $11.4^\circ$ . The standard deviation of the rotation angle (around the rotation error mean) varied from  $4.4^\circ$  to  $22.9^\circ$ . The most significant complication of this method was that the logs might sway on the conveyor (Vuorilehto & Tulokas 2007). From the rotation point of view, the log sway means that a log is measured in a different position compared to when it arrives at the rotation mechanism. Even if

the rotator executes the optimized rotation command correctly, the rotated log is not in the optimal position for cutting, regardless of the accuracy of log measurement, optimization software and PLC control. At its worst, the log sways already when it is being measured and the log is incorrectly optimized.

In automatic log rotation with *two measuring systems* the average rotation error varied from  $-2.6^\circ$  to  $+0.5^\circ$ . The standard deviation of the rotation angle varied from  $7.7^\circ$  to  $18.3^\circ$ . Nonetheless, this kind of correction method of the rotation angle has a deficiency: the method helps correct the rotation error average but not the deviation of the rotation angle (around the rotation error mean).

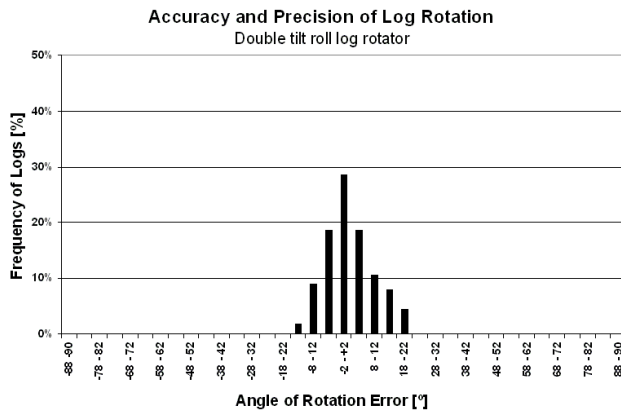
The reliability of log rotation with a *real time in-line measurement* has been investigated with a 10-20-time repeat test for 10 logs and a 2-time repeat for 100 logs of different sizes. The test results with 10 logs show that the average of the standard deviation of log positions was  $6^\circ$ . The standard deviation of the absolute value of position deviation tested with 100 logs was  $9^\circ$ . When comparing this real time method to other log rotation methods we should notice that in addition to the rotation error, these results also include a log measuring error.

### *Log rotation mechanics*

The best standard deviation value in a *tilt roll log rotator* was recorded at  $6^\circ$ . In tilt roll log rotators it is important that the rolls position themselves correctly before the rotation and that they tilt and turn correctly and timely during the log rotation. In one system it was observed that, seen from the feed direction, the first right hand tilt roll's starting position was in an angle of  $2.3^\circ$  towards the feed direction. As a consequence, the logs optimized for clockwise rotation were over-rotated and the counter-clockwise logs were under-rotated.

Due to the non-homogeneous nature of wood, the greatest weakness of a tilt roll log rotator is that the rolls move along the log's surface. To ensure the functioning of the control system, the computer program has been simplified in order to minimize the number of calculations needed. The program determines when and how much the tilt rolls should be tilted. If the logs are elliptic, the rotation process becomes more difficult because the rolls do not travel the same distance as they would if they were rotating a completely round log. This problem is also encountered if the log is cone-shaped or has knots. The rolls travel the same distance on both sides, which alone makes the rotation distorted if the log is not rotationally symmetrical. (Kempainen 2005) If there is slipping between the log and tilt rolls during the rotation, the log rotator is

not aware of it. In consequence, the rotation may be incomplete. If only some of the logs slip, the deviation of the rotation angle increases, which in turn decreases the sawing yield. In Figure 10 a typical Gaussian distribution of tilt roll log rotation is shown.

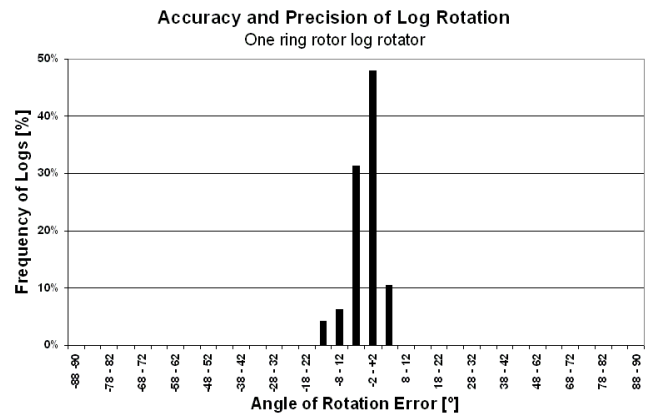


**Figure 10.** The normal distribution of rotation errors indouble tilt roll rotator study. The rotation error average ( $\bar{X}$ ) was  $+2.3^\circ$ . Rotations exceeded the target angle by about  $2.3^\circ$  on average. The deviation of the rotation angle ( $s$ ) around the average was about  $8.3^\circ$ . The rate of correct rotations was 76.1 %

The best standard deviation value in a one-ring rotor log rotator was graded at  $4^\circ$ . Rotor rotators can be very accurate and precise because the rotation does not take place following the surface shape of a log, but by turning a metallic ring. As with the tilt roll rotators, the most important factor in rotor rotators is that the rolls hold the logs firmly when the rotation starts and keeps them in grip during the whole time of rotation. In one study, it was observed that the sequence of the holding rolls and the rotation of the ring were not synchronous. Sometimes the ring rotated actively, but the logs did not rotate accordingly because the rolls did not hold them. The resulting rotation error average was  $-53.4^\circ$  and the standard deviation of the rotation angle error was  $36.4^\circ$ . In Figure 11 a Gaussian distribution of rotor log rotation is shown.

Research information about *vertical log rotator* accuracy is not available. At best, the accuracy is presumed the same as with the tilt roll log rotator. The log's geometry has the same effect on the rotation result of the vertical rotator as on that of the tilt roll rotator. That is, an elliptic or cone-like shape or knots on the surface of the log affect the rotation result. As with the tilt roll rotators, there may be some slipping, which can result in incomplete rotation and augment the deviation of the rotation angle.

The reliability of log rotation with a *real time in-line measurement* has been investigated with a 10-20-time repeat test for 10 logs and a 2-time repeat for 100



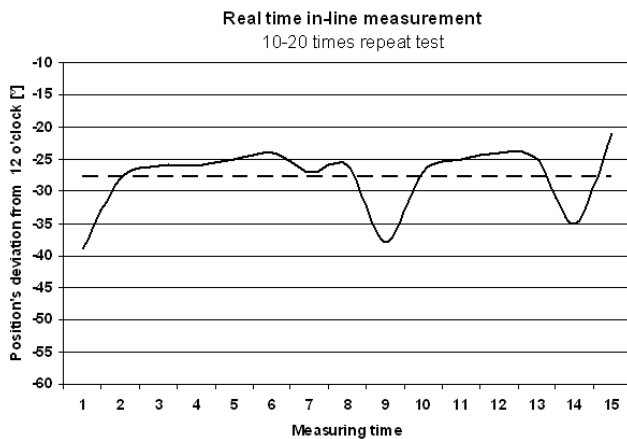
**Figure 11.** The normal distribution of rotation errors indouble tilt roll rotator study. The rotation error average ( $\bar{X}$ ) was  $-2.0^\circ$ . Rotations stayed incomplete by about  $2.0^\circ$  from the target angle an average. The deviation of the rotation angle ( $s$ ) around the average was about  $4.5^\circ$ . The rate of correct rotations was 93.8 %.

logs of different sizes. Test results with 10 logs show that the average standard deviation of log positions was graded at  $6^\circ$ . The standard deviation of the absolute value of position deviation with the 100 log test was graded at  $9^\circ$ . According to the manufacturer of the equipment, the accuracy of the log rotation system is in practice about 1 %. Additionally, the manufacturer also reports that with their technology it is possible to obtain savings of 5 % in the use of log raw material. When comparing this real time measuring technology to other log rotation techniques we should notice that in addition to the rotation error, these results also include a log measuring error.

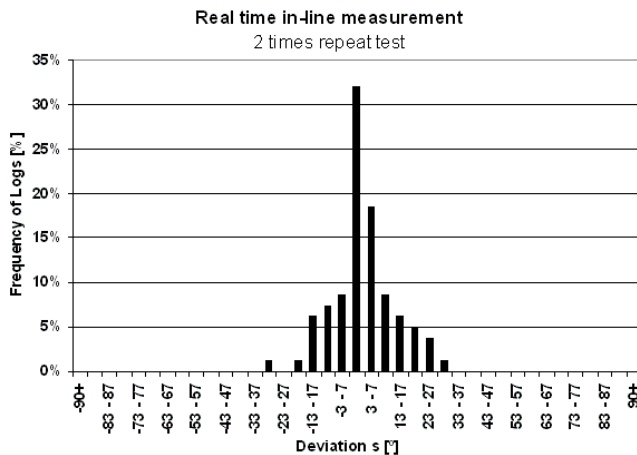
One of the weaknesses of the rotator could be the fact that the 2D measurements do not recognize elliptic shapes, which can lead to loss of raw material in straight and elliptic logs. The rotation mechanics of the rotator, as others of its kind, is susceptible to incorrect positioning due to the roll slipping and bouncing (knots). One of the strengths of the rotator is continuous measurement, due to which the rotator can assess how the rotation will progress and succeed. In Figure 12 a result of 10-20-time repeat test for 10 logs is shown. In Figure 13 a result of 2-time repeat for 100 logs is shown.

### Discussion and Conclusions

Sawmill personnel often has an idea of what correct log rotation is. The idea of correct log rotation is based on visual observations on how the log rotates in the process and whether the log scaler's optimized rotation angles change on the log scaler's display. Nevertheless, studies have shown that although the



**Figure 12.** Log's position deviation between repeats in real time in-line measurement repeat test for one log. The standard deviation of log positioning was (s) was  $5.3^\circ$ . The average of position (X) was  $-27.7^\circ$



**Figure 13.** The normal distribution of rotation errors in real time in-line measurement repeat test for one log. The standard deviation of absolute value of deviation (s) was  $7.9^\circ$ . The rate of correct rotations was 71.6 %

log scaler optimizes the log rotation angel and the log rotator rotates the log in the right direction, it is very hard to visually observe whether the log rotated for example  $20^\circ$  or  $45^\circ$  in the log rotation process.

Studies indicate that a typical situation in most Finnish sawmills is that the rotation error average deviates often clearly from zero: rotations might stay incomplete over  $20^\circ$  on average or they went clearly over on average from the target rotation angles. Additionally, the standard deviation of the rotation angle was often large, even over  $30^\circ$ . The average deviation from zero and large standard deviation decrease the rate of successful rotations ( $|A| \leq 10^\circ$ ), which decreases the volume yield of sawing.

The correct rotation with softwood can be "sweep up" for the log position that yields the best solution. The required rotation precision (standard deviation around the average) by experts is often stated as better than  $5^\circ$ . Usenius (2002) recommends that the precision should be better than  $2^\circ$  for optimal sawing including value optimizing with tomography. A larger deviation quickly leads to reduced volume and value recovery in sawing. The true application of value optimizing in log rotation can, however, take years. Studies have shown that currently the best log rotators can achieve a deviation of  $4^\circ$ . The typical deviation value for automatic log rotators at sawmills is 10 -  $15^\circ$ . This presents a challenge for improving the log rotation process and utilizing tomography in the sawing process.

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## УЛУЧШЕНИЕ ТЕХНОЛОГИИ ПОВОРОТА БРЕВНА

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### *Резюме*

На лесопильных заводах используется несколько различных способов поворота бревен – от ручного поворота до поворота с измерением в режиме реального времени. Кроме того, осуществляется эта операция на заводах с помощью различных механизмов разных производителей, которые, как правило, имеют собственное мнение о том, какой механизм лучше всего подходит для разных видов лесопильного оборудования. Максимального полезного выхода можно добиться, если при использовании систем сканирования и оптимизации средний разброс угла поворота бревна будет составлять менее 2°. Обычно на лесопильных заводах этот показатель при автоматическом повороте равен 10° – 15°. Таким образом, стоит непростая задача по улучшению технологии поворота бревна, чтобы при первом проходе распиловки добиться максимального полезного выхода.

Если на лесопильном заводе система поворота бревен не действует должным образом, это обычно связывают с самим устройством поворота бревна. Исследования, однако, показывают, что на успешную работу системы влияют многие другие факторы – начиная с конвейера бревен и заканчивая передачей данных между компьютерных систем, задействованных в повороте бревен. В данной статье рассматриваются методы поворота бревна, используемые на лесопильных заводах, а также различные поворотные механизмы и влияние их характеристик на точность поворота. Статья и отмеченные в ней выводы основаны на данных исследований систем поворота бревен, проведенных в 2003 – 2005 годах на нескольких финских лесопильных заводах.

**Ключевые слова:** поворот бревна, устройство поворота бревна, распиловка, оптимизация, точность, полезный выход