

Analysis and Design of the Control Strategy of Three-roll Rewinder

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Abstract: By dividing the rewinding process of a three-roll rewinder into three zones, mathematical equations were formulated and diagrams were drawn to determine the structure factors of the rewinder, such as the diameters and spatial distribution of the rewinding rolls. The qualitative and quantitative analysis results show that the roll gap of the first two rewinding rolls and the angle between the line that connects the center points of the first two rewinding rolls and the vertical line play an important role in determining the ideal log diameter, which is related to the production capacity of the rewinder. Additionally, the ideal roll gap has a significant effect on the spatial distribution of the three rewinding rolls, the rewinding dead zone, and the rewinding quality of the log, which should be taken into full consideration when designing and improving rewinders to enhance production efficiency and satisfy ultra-high quality requirements.

Keywords: paper machine; rewinder; ideal log; ideal drum gap; rewinding dead zone

1 Introduction

During the papermaking process, the web is generated on a forming fabric; then, it is usually dried and wound in reels with large diameter. These reels are subsequently unwound and rewound using cardboard rewinding cores that are inserted into a rewinding machine to form logs with smaller diameter. These logs are subsequently divided into the end product, such as toilet paper and kitchen towel^[1-2]. In other rewinders, the rewinding process is conducted around extractable and recyclable mandrels, which are withdrawn from the log after the rewinding process has been completed. The rewinders that do not use rewinding cores or mandrels have also been manufactured; these rewinders rewind the log by forming a central nucleus, which starts to rewind around itself^[1, 3-6].

Some studies have been carried out to optimize the log-formation process and



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improve the quality and performance of the log. The research result of Li et al showed that a steady web tension, the appropriate torque of the three rolls in a three-roll rewinder, and effective pressure control of the rider roll which exerted pressure on the log to control its compactness, were the three basic factors that played important roles in the compactness of the logs^[7]. In another study, the production and variation of the web tension and the speed difference of the rolls in a toilet paper rewinder were examined. The study indicated that there was no simple linear relationship between the web tension and the speed difference of the rolls. Furthermore, it suggested that the initial state of the web might be considered as a dynamic input variable in the analytical calculation of the web tension^[8]. In the log formation process, the rider roll exerts a pressure on the log owing to the change of the rewinding radius. And the pressure can be controlled by employing a proportional decompression valve to modulate the oil pressure in the hydraulic cylinder. This, in turn, aids in negating the influence of the pressure mentioned above on the compactness of the log^[9]. Moreover, the calculation of the diameter of the unwinding reels or rewinding logs should be performed in real time to maintain a stable and controllable web tension^[10]. Fabio Perini has developed a new rewinding system named Constellation, which can offer good rewinding quality by employing four mobile rolls with independent drives to prevent vibrations and achieve higher speeds. This rewinding system is efficient for producing extremely soft scrolls when the embossment should be preserved, maximizing the quality of the finished product^[11].

Previous studies have either placed more emphasis on program debugging for a given rewinder or have focused on a specific type of log. Furthermore, several rewinding defects that occur in real production have not been discussed or resolved effectively and comprehensively. The flattening of the log and tearing of the outer sheet are attributed to the inefficient design of the three rewinding rolls. Frequent occurrences of overloading of the motor or the damage of the shaft coupling are a result of an extremely long rotary arm

of the third rewinding roll. Bad compactness, which is characterized by loose interior sheets and dense exterior sheets in the whole log, results in difficult and inefficient post-processing. This study examined the log rewinding process from a new perspective and proposed a parametric analysis based on several mechanical structure factors for application in the design and optimization of rewinders.

2 Rewinding process

Generally, the rewinding area of a three-roll rewinder comprises three rewinding rolls. A roll gap of the first two rolls is defined to allow the passage of the web. The third rewinding roll is supported by a pair of arms that pivot with a reciprocating movement towards or away from the other two rolls. This movement depends on the diameter of the log that is formed inside the rewinding cradle, which is defined by the three rolls.

A feed channel of the web (denoted as N in Fig.1) is located between the surface of the concave plate that faces the first rewinding roll and the lateral surface of that roll. This channel is guided around the first rewinding roll and, by successive rewinding cycles, the above web is wound to form a number of logs.

The path of the web extends around the first rewinding roll, enters the channel and then passes through the roll gap of the first two rewinding rolls to feed the web into the rewinding cradle.

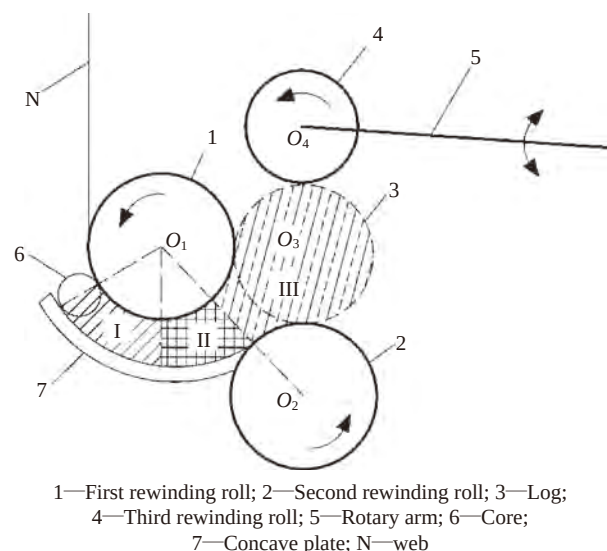


Fig.1 Division of the three-zone rewinding process

The log rewinding process can be described as follows. Firstly, the web is fed around the first rewinding roll and the first log is wound. Secondly, when the rewinding of the first log is completed, the web is severed along a perforated straight line across the web; thus, the free trailing edge of the first log and the free leading edge of the second log are formed. Thirdly, the portion of the web that is adjacent to the free leading edge is wound between the surface of the first rewinding roll and a moving member to form the initial nucleus of the second log. In the last step, the initial nucleus of the second log is transferred into the feed channel and rolled along the channel to contact the concave plate and the first rewinding roll. Then, the rewinding of the web continues to start a new rewinding cycle.

Based on the process described above, the rewinding region of a three-roll rewinder can generally be divided into three successive zones: the nucleus formation zone, the creeping zone, and the rewinding zone. As shown in Fig.1, the nucleus formation zone, marked as zone I, starts from the position where the core is in contact with the first roll or where the paper head begins to stack to form the rewinding nuclear and ends at the completion of the rewinding nucleus. Next to the nucleus formation zone is the creeping zone, denoted as zone II, which ends at the line connecting the center points of the first and second rewinding rolls or at the roll gap. Downstream of the roll gap is the rewinding zone, represented as zone III, where the majority of the log is rewound using the three rewinding rolls. It is obvious that zone I completes the formation of the initial nucleus of a new log, zone II transfers the nucleus toward the channel to increase the log diameter, and zone III rewinds the log until the target diameter is reached. In certain other cases (in particular, in a coreless rewinding process), the nucleus formation process takes place near the roll gap and the rewinding process begins immediately, without the creeping motion. Then, the rewinding region consists of only one zone, in which the nucleus formation and rewinding processes proceed in succession. In this paper, the main

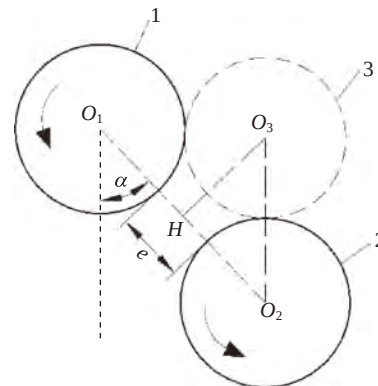
discussion concerns the three-zone division, and the results can also be applied to the one-zone situation. The following section mainly discussed the key issues of a three-roll rewinder design and their solution.

3 Results and discussion

3.1 Ideal log diameter

Considering the known diameters of the rewinding rolls, the obtainable log diameter is limited by the spatial arrangement of the first and second rewinding rolls. This spatial arrangement is defined by the roll gap of the first two rolls and the angle between the center point line that connects the first two rewinding rolls and the vertical line. For a certain roll gap and angle, the wound log can easily advance downstream using a small force when the line connecting the center points of the log and the second rewinding roll is a vertical line. Then, the ideal log diameter is determined. It can be seen that the ideal log diameter mainly favors the rewinding process, and the diameter of the produced log should be as consistent as possible with the ideal log diameter. In this paper, the relationship between the spatial arrangement parameters (the roll gap and angle), and ideal log diameter is discussed.

In Fig.2, the radii of the first and the second rewinding rolls are r_1 and r_2 ($r_1=r_2$), respectively, the gap between the two rolls is e , the angle between the center point line that connects the first two rewinding rolls and the vertical line is α ($\angle O_3O_2O_1=\alpha$), and the



1—The first rewinding roll; 2—The second rewinding roll;
3—The ideal log

Fig.2 Arrangement of the rolls and the ideal log

radius of the log is r_3 (log diameter $D=2r_3$). When r_1 is equal to r_2 , the center point (O_3) of the log must be on the perpendicular bisector of the center point line (O_1O_2) that connects the first and second rewinding rolls, with the foot of the perpendicular denoted as H . Therefore:

$$O_2H = \frac{O_1O_2}{2} = \frac{r_1+r_2+e}{2} = \frac{2r_2+e}{2} \quad (1)$$

As can be seen in Fig.2, $O_2H \perp O_3H$, so ΔO_2HO_3 is a right triangle. Therefore:

$$O_2O_3 = \frac{O_1H}{\cos\alpha} \quad (2)$$

Because D is equal to $2r_3$, substituting Eq.(1) and Eq.(2) into D , therefore:

$$D = 2r_3 = 2(O_2O_3 - r_2) = \frac{2r_2+e}{\cos\alpha} - 2r_2 \quad (3)$$

In a practical production process, the values of r_2 , e , and α ($r_2=100$ mm, $e \in [4, 80]$, and $\alpha \in [20^\circ, 80^\circ]$) are substituted into Eq.(3). The effect of e and α on D is shown in Fig.3.

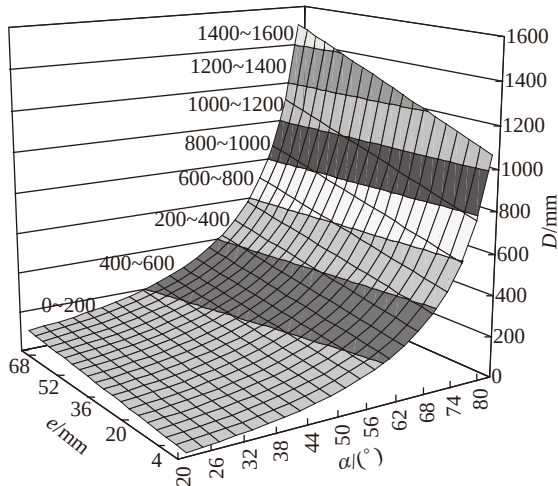


Fig.3 Relationship between the ideal log diameter and the arrangement parameters

As seen in Fig.3, the relationship between the ideal log diameter and the arrangement parameters (e and α) is a concave curved surface and the ideal log diameter increases with e and α . When the values of e and α are $[4, 80]$ and $[20^\circ, 60^\circ]$, respectively, the ideal log diameter increases slowly, which indicates that e and α have a relatively small impact on the ideal log diameter. When the values of e and α are $[4, 80]$ and $[60^\circ, 80^\circ]$, respectively, the ideal log diameter increases sharply,

which indicates that e and α have a significant impact on the ideal log diameter.

A plane parallel to the bottom surface of the concave curved surface (Fig.3) is used to cut a 3D figure, and a curved section is generated, i.e., for a particular ideal log diameter, there are several pairs of roll gaps and angles.

The pie chart of Fig.4 is the statistical analysis result of the ideal log diameter distribution when the values of e and α are $[4, 80]$ and $[20^\circ, 60^\circ]$, respectively. Fig.4 shows that the ideal log diameter below 400 mm occupies approximately 74% of the pie chart. This indicates that rewinders with such roll diameters are mainly appropriate for rewinding logs with diameter below 400 mm.

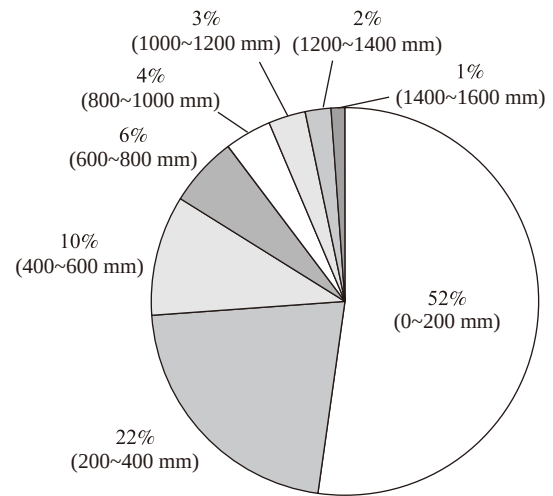


Fig.4 Distribution of the ideal log diameter

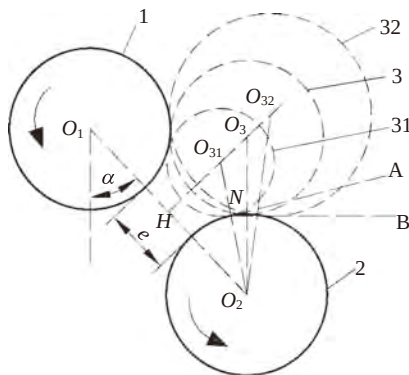
From Fig.3 and Fig.4, it can be concluded that the ideal log diameter reflects the relationship between the size of the ideal log that a rewriter can rewind and the spatial distribution of the rewinding rolls, which can guide the design and optimization of the first and second rewinding rolls according to the different diameter requirements of the target logs.

3.2 Modified log diameter

In practical production, the common requirement is to produce logs with different diameters by using the same distribution of the three rewinding rolls. Thus, it is necessary to modify the ideal log diameter to extend the diameter range of a log that a three-roll rewriter can

rewind.

As shown in Fig.5, the target log diameter is either smaller or larger than the ideal log diameter. In the former case, the log is designated as log 31 and, in the latter case, as log 32; the centers of the two logs are labeled O_{31} and O_{32} , respectively. The angle $\angle O_3O_2O_{31}$ is that formed between the line O_2O_{31} that joins these centers and the vertical direction, and $\angle ANB$ is that defined between the horizontal line and the common tangent of the log with the second rewinding roll. The angle $\angle ANB$ is the ejection angle, at which the wound log rolls away from the rewinding region. It is clear that the larger the angle is, the farther the log is from the highest point of the second rewinding roll and the more difficultly the log is ejected out from the rewinding region. Often, the log shifts into the downstream channel. The above-mentioned analysis has also been applied to log 32; in this case, a larger angle requires a higher force of the third rewinding roll to support the log, impeding the control of the rewinding process because of the increased load of the third rewinding roll.



1—The first rewinding roll; 2—The second rewinding roll;
3—The ideal log

Fig.5 Modified log diameter

Based on the above analysis, the spatial distribution and diameters of the first and the second rewinding rolls define a unique ideal log diameter. Hence, it is necessary to control the size of the log diameter and reduce the ejecting angle of the log appropriately to determine the size of the logs being produced. This results in a relation between the modified log diameter and arrangement parameters (e and α) for various

ejecting angles. For clarity, the ideal log diameter is denoted as D_i and the produced log diameter is represented as D with a radius r .

Because $AN \perp O_2O_{31}$ and $BN \perp O_2O_{32}$, $\angle O_3O_2O_{31} = \angle ANB$. Furthermore, $\beta = \angle ANB$, for log 31, β can be readily determined as:

$$\beta = \alpha - \angle O_{31}O_2H = \alpha - \arccos \frac{O_2H}{O_2O_{31}} = \alpha - \arccos \frac{2r_2 + e}{2(r_2 + r)} \quad (4)$$

Similarly, for log 32, β can be readily determined as:

$$\beta = \angle O_{32}O_2H - \alpha = \arccos \frac{O_2H}{O_2O_{32}} - \alpha = \arccos \frac{2r_2 + e}{2(r_2 + r)} - \alpha \quad (5)$$

Combining Eq.(4) and Eq.(5) yields:

$$|\beta| = \left| \arccos \frac{2r_2 + e}{2(r_2 + r)} - \alpha \right| \quad (6)$$

In practice production, a realistic value of β is:

$$|\beta| \leq 5^\circ \quad (7)$$

By substituting Eq.(7) into Eq.(6), and solving for the log diameter D gives:

$$\frac{2r_2 + e}{\cos(\alpha - 5^\circ)} - 2r_2 \leq D \leq \frac{2r_2 + e}{\cos(\alpha + 5^\circ)} - 2r_2 \quad (8)$$

By substituting $r_2 = 200$ mm and $\alpha = 45^\circ$ into Eq.(8), the relationship between D and e is obtained, which is shown in Fig.6. The minimum diameter, the maximum diameter, and the ideal diameter of the log increase with the roll gap (e), and the ideal diameter is slightly

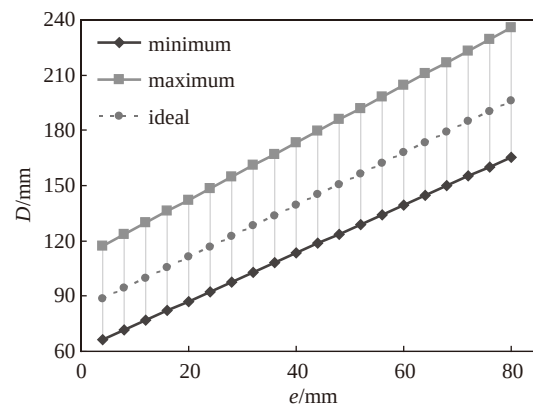


Fig.6 Relation between log diameter and roll gap

smaller than the mean value of the minimum and maximum diameter. The difference value between the minimum and maximum diameter increases with increasing roll gap, which is shown in Fig.6.

By substituting $r_2=200$ mm and $e=40$ mm into Eq.(8), the relationship between D and α is obtained, which is shown in Fig.7. The minimum, the maximum, and the ideal values of the log diameter increase non-linearly with α . As shown in Fig.7, the ideal diameter is slightly smaller than the mean value of the minimum and maximum diameters, and the difference value between the minimum and the maximum diameters increases as α increases. In contrast to Fig.6, Fig.7 shows that the difference value between the minimum diameter and the maximum diameter, and that between the ideal diameter and the mean value of the minimum and the maximum diameters both increase distinctly when α is over 65° .

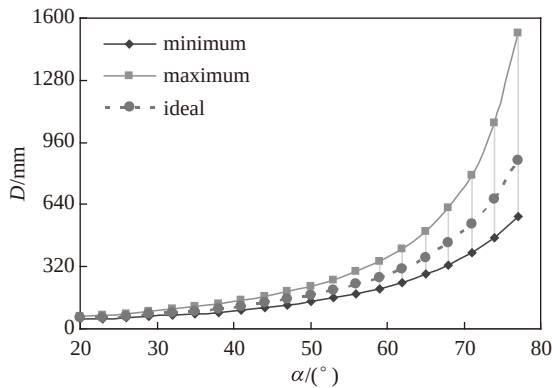


Fig.7 Relationship between log diameter and α

By analyzing Fig.6 and Fig.7, it is evident that the range of log diameter that satisfies the ejecting angle varies according to the ideal log diameter, which greatly widens the size of a log that a rewinder can rewind. The relationship inferred above can provide guidance for the design and improvement of the mechanical structure of a rewinder.

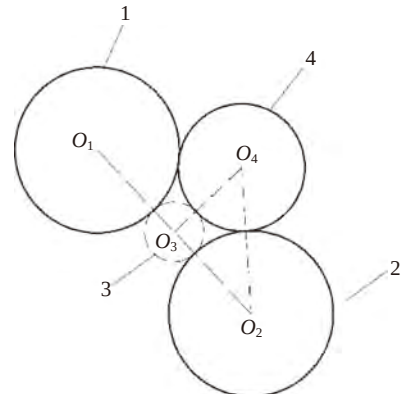
3.3 Ideal roll gap

From the above discussion, it is clear that the feasible domain of the roll gap (e) and the angle (α) can be calculated for the given diameter or diameter range of logs. However, the final values of these parameters

cannot be determined only based on the above data. Additional information needs to be taken into consideration to fully determine the position of the three rolls in a three-roll rewinder.

Therefore, the position of the third rewinding roll is analyzed. The position of the third rewinding roll changes with the increase of the log diameter. Usually, the curve is a circular arc with three elements; namely, the start point and the end point of the circular arc, and its radius.

The lowest point of the third rewinding roll, i.e., the moment when the roll contacts the nucleus of the log, is shown in Fig.8. When the log nucleus moves to the position of the roll gap, the center of the log is located on the line joining the centers (O_1O_2) of the first and second rolls. At this point, if the log nucleus is tangent to the three rewinding rolls, the roll gap at that moment is called the ideal gap.



1—First rewinding roll; 2—Second rewinding roll;
3—Ideal log; 4—Third rewinding roll

Fig.8 Internal common tangent circle of the three rewinding rolls

The diameter of the log nucleus is equal to the diameter of the internal common tangent circle of the three rewinding rolls, i.e.,

$$e=D=2r_3 \quad (9)$$

The radius of the third rewinding roll is denoted as r_4 . Because $O_3O_4 \perp O_1O_2$, $\triangle O_2O_3O_4$ is a right triangle. Therefore:

$$O_2O_3^2 + O_3O_4^2 = O_2O_4^2 \quad (10)$$

i.e.,

$$(r_3+r_2)^2 + (r_3+r_4)^2 = (r_2+r_4)^2 \quad (11)$$

Solving for r_3 and substituting the solution into Eq.(9) gives:

$$e = \sqrt{r_2^2 + r_4^2 + 6r_2r_4 - r_2 - r_4} \quad (12)$$

The substitution of r_2 ($r_2 \in [90, 190]$) and r_4 ($r_4 \in [40, 60]$) into Eq.(12) yields the relationship of e with r_2 and r_4 , as shown in Fig.9. As the diameters of the three rewinding rolls increase steadily, the ideal roll gap widens gradually and achieves a unique value for each roll. In this manner, the spatial distribution of the three rewinding rolls can be determined by the diameters of the rewinding rolls and logs because α and e are fully defined.

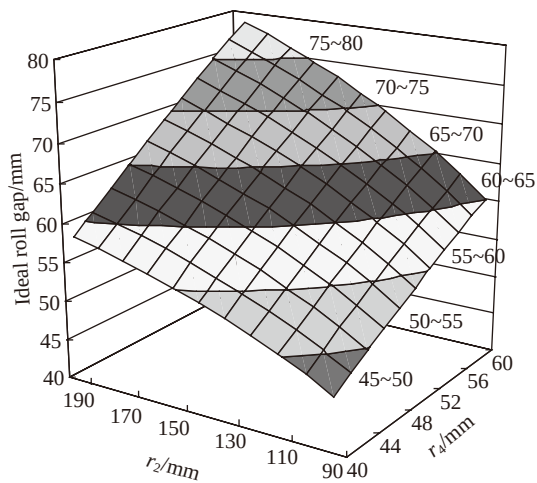


Fig.9 Relationship of the ideal roll gap with the roll diameters

In practice, the roll gap is not always equal to the ideal roll gap, as shown in Fig.10 and Fig.11. In Fig.10, the third rewinding roll is in contact with the log nucleus, although it is separated from the first and second rewinding rolls, and the diameter of the internal

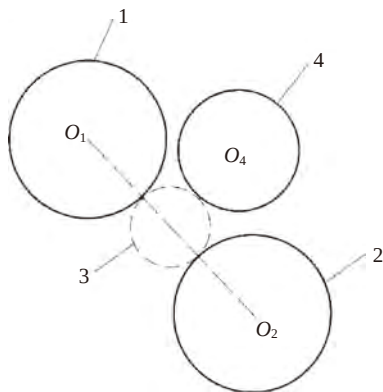


Fig.10 Roll gap that is larger than the ideal roll gap

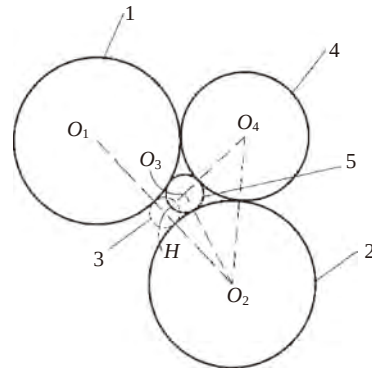


Fig.11 Roll gap that is smaller than the ideal roll gap

common tangent circle defined by the three rewinding rolls is larger than the log diameter. Considering another situation in Fig.11, where the roll gap is smaller than the ideal roll gap, when the log nucleus advances into the roll gap, the third rewinding roll separates from the log nucleus while being in contact with the first and second rewinding rolls. In this case, the diameter of the internal common tangent circle defined by the three rewinding rolls is also larger than the log diameter.

Comparing the two above situations, the third rewinding roll in Fig.10 can immediately contact the log nucleus when it advances across the roll gap into the rewinding region. This makes it easy to control the log compactness by adjusting the pressure of the third rewinding roll on the log. In contrast, the third rewinding roll in Fig.11 cannot contact the log nucleus promptly when the nucleus advances into the rewinding region. The rewinding process proceeds only because of the differential drives of the first and second rewinding rolls. In this case, the nucleus enters the rewinding region easily; this makes it difficult to control the rewinding process and results in the generation of log defects. Because defects occur when the process involves only two rewinding rolls without the participation of the third rewinding roll, this rewinding region is called the rewinding dead zone. To avoid such structural problems in the design projects, a quantitative analysis of the rewinding dead zone in Fig.11 is conducted.

To simplify the description of the quantitative analysis of the rewinding dead zone, the diameter of

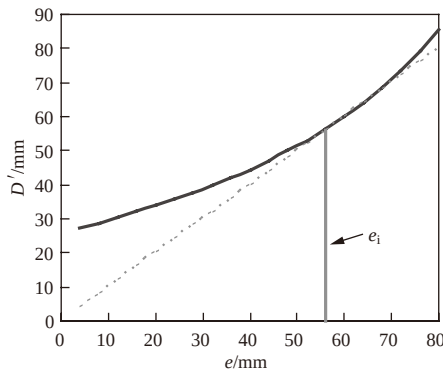


Fig.12 Relationship of roll gap with the diameter of the internal common tangent circle

the internal common tangent circle defined by the three rewinding rolls is denoted as D' ($D'=2r_5$), and the ideal roll gap is represented as e_i . Therefore:

$$O_3O_4 = O_4H - O_3H = \sqrt{O_4O_2^2 - O_2H^2} - \sqrt{O_3O_2^2 - O_2H^2}$$

and $O_3O_4 = r_4 + r_5$

Solving for e gives:

$$e = 2 \sqrt{(r_5 + r_2)^2 - \frac{[(r_4 + r_2)^2 - (r_5 + r_4)^2 - (r_5 + r_2)^2]^2}{4(r_5 + r_4)^2}} - O_2H^2 - 2r_2 \quad (13)$$

Substituting r_2 ($r_2=100$ mm) and r_4 ($r_4=50$ mm) into Eq.(13) yields the relationship of e with D' , as depicted in Fig.12.

As can be seen in Fig.12, the ideal roll gap is a critical value, and that $e=e_i$, $e>e_i$, and $e<e_i$ correspond to Fig.8, Fig.10, and Fig.11, respectively. To express this more clearly, an auxiliary line has been drawn in the plot, on which the roll gap is equal to the diameter of the internal common tangent circle defined by the three rewinding rolls. This auxiliary line intersects with the relation curve at one point when e equals the ideal roll gap. When e is smaller than e_i , the zone under the relationship curve is the rewinding dead zone because the third rewinding roll does not contact the log nucleus at the very beginning of the advancement of the log nucleus into zone III (Fig.1). It is obvious that a smaller roll gap corresponds to a larger rewinding dead zone, and vice versa. When e is larger than e_i , there is no rewinding dead zone theoretically. In practice, the situation that e is equal to e_i does not exist because the third rewinding roll cannot actually contact the first and

the second rolls, and the roll gap should be larger than the ideal roll gap when designing rewinders. If there are strict conditions requiring that the roll gap cannot be larger than the ideal roll gap, it is recommended that the roll gap is as close as possible to the ideal roll gap to minimize the area of the rewinding dead zone.

3.4 Top dead center of the third rewinding roll

According to the above discussion, for a three-roll rewriter, the spatial distribution of the first two rewinding rolls can be certain as long as the required log diameter is defined. The bottom dead center of the third rewinding roll is located on the line joining the centers of the first two rewinding rolls, so the lowest position of the third rewinding roll is determined. Then, it is necessary to ascertain the top dead center of the third rewinding roll for the full calculation of the motion curve of the third rewinding roll.

Fig.13 displays the final position where a log has been completely wound by the three rewinding rolls. In Fig.13, line O_4K is perpendicular to line O_2O_3 , where K denotes the foot point, $\angle O_4O_3K$ is represented as θ , and the roll gap between the second and third rewinding rolls is represented as m .

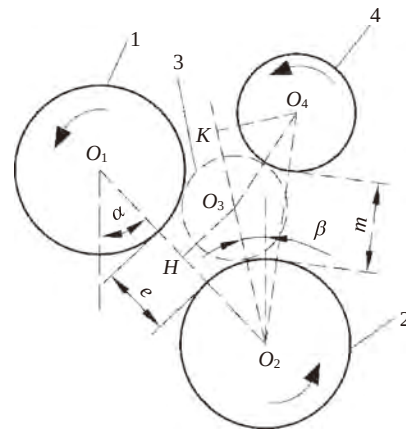


Fig.13 Top dead center of the third rewinding roll

The triangle $\Delta O_2O_3O_4$ is a right triangle and therefore:

$$O_4K = O_3O_4 \sin \theta \quad (14)$$

$$O_3K = O_3O_4 \cos \theta \quad (15)$$

$$O_2O_4 = \sqrt{O_4K^2 + (O_3K + O_2O_3)^2} \quad (16)$$

$$m = O_2O_4 - r_2 - r_4 \quad (17)$$

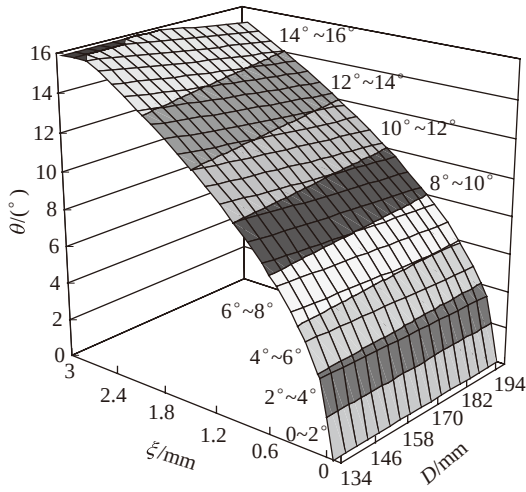


Fig.14 Relationship of the top dead center with the log diameter and damping quantity

$$2r - m = \xi \quad (18)$$

where ξ is the damping quantity of the log ejected from the rewinding zone, and usually $0 \leq \xi \leq 3$. Substituting Eq.(14)~Eq.(17) into Eq.(18) and solving for θ gives:

$$\theta = \arccos \frac{(2r + r_3 + r_2 - 3)^2 - (r + r_3)^2 - (r + r_2)^2}{2(r + r_3)(r + r_2)} \quad (19)$$

The diameter of the first rewinding roll is denoted as D_1 and that of the third rewinding roll as D_3 . Suppose $D_1 = 200$ mm, $D_3 = 100$ mm, $\alpha = 45^\circ$, $67.1 \text{ mm} \leq r \leq 99.13 \text{ mm}$, and the ideal roll gap (e_i) is 56 mm. Substituting these values into Eq.(19) yields the relationship of θ with D and ξ , as shown in Fig.14.

Fig.14 is a 3D convex surface. Each pair of log diameter and damping quantity is associated with a unique top dead center of the third rewinding roll. This implies that once the diameter of the log produced and the ejecting damping quantity are determined, the topmost point of the reciprocating motion curve can be determined for the third rewinding roll. The radius of the reciprocating motion curve can also be determined by using other factors, such as the web width, wallboard width, and the complexity of the control for the third rewinding roll. Thus, the start and end points and radius of the reciprocating motion curve can be determined for the third rewinding roll. Therefore, the spatial distribution of the three rewinding rolls can be fully

described.

4 Conclusions

Several key points for designing and improving a three-roll rewinder are discussed qualitatively and quantitatively in this paper, which are summarized as follows.

4.1 Based on the target log diameter supplied by clients, the feasible region of the roll gap of the first two rewinding rolls and that of the angle between the line that connects the center points of the first two rewinding rolls and the vertical line are determined, and the ideal log diameter is chosen to be as close to the median value of the feasible regions as possible.

4.2 A three-roll rewinder with roll diameters determined has a unique ideal roll gap. For a core rewinding process, there is a core with a diameter equal or larger than the ideal roll gap. For a coreless rewinding process, there is a rewinding dead zone that should be minimized to improve the quality of the log. During the design process, the dead zone must be fully considered when evaluating the effect of the ideal roll gap on the rewinding process.

4.3 The motion of the third rewinding roll is a reciprocating rotation movement around a fixed point, and its motion curve is usually a circular arc centered at that point. The start point of the circular arc is located on the line connecting the centers of the first two rewinding rolls, the end point of the circular arc is determined by the target log diameter and the ejection damping quantity, and the radius of the circular arc is restricted by the wallboard width and other parameters.

4.4 The mechanical structure of a rewinder varies with the diameters of the target logs supplied by clients. Even for the same rewinding structure, the mechanical design and electrical control may differ because of the different web tension, basis weight, and processing, such as embossment or glue lamination.

References

- [1] Graziano Mazzaccherini, Romano Maddaleni, Franco Montagnani. Rewinding machine and method for producing logs of web material: US, 9365379B2[P]. 2016-06-14.

- [2] Giulio Betti, Angelo Benvenuti, Roberto Morelli. Rewinding machine and method for winding up rolls of web material on extractable mandrels: US, 6752345B2[P]. 2004-06-22.
- [3] Eva Perini, Guglielmo Biagiotti. Rewinding machine and method for the formation of logs of web material with means for severing the web material: US, 5979818[P]. 1999-11-09.
- [4] Guglielmo Biagiotti. Machine and method for the formation of coreless logs of web material: US, 5839680[P]. 1998-11-24.
- [5] Guglielmo Biagiotti. Rewinding machine for coreless winding of a log of web material with a surface for supporting the log in the process of winding: US, 5538199[P]. 1996-07-23.
- [6] Fabio Perini. Web winding apparatus and method: US, 4487377[P]. 1984-12-11.
- [7] LI Pei-yi, WANG Zhi-jie, DONG Xian-min. Winding tightness control of the WINRoll winder[J]. China Pulp & Paper, 2006, 25(8): 38-39.
- [8] LI Jie-chao. Web tension calculation of rewinder[J]. Transactions of China Pulp and Paper, 2015, 30(1): 50-55.
- [9] GUO Yan-ping, YANG Wei-bing. Pressure control principle and scheme of rewinder's platen[J]. China Pulp & Paper, 2010, 29(7): 56-57.
- [10] GAO Wei-xiao, GUO Yong-hong. The application of accessory S00 of SIEMENS in self-adjusting reel diameter calculation[J]. China Pulp & Paper, 2011, 30(8): 52-53.
- [11] Fabio Perini Company. Constellation: The only limit is your imagination[DB/OL]. <http://www.fabioperini.com/en/news/constellation-only-limit-your-imagination>. PBM