Changes of Sliver Irregularity in Two-Zone Roller Drafting

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Abstract

A theoretical calculation is made to simulate the effect of drafting upon the sliver irregularity in two-zone drafting of three-over-three roller system. Two types of slivers, i.e., random sliver and optional sliver are considered. The effects of sliver count, staple fiber length, fineness of fiber, draft distribution between two drafting zones, maximal moving distance and distribution type of speed changing point are calculated on a computer. Furthermore, we have a try for clarifying the relation between irregularity of the supplied sliver and irregularity due to the movement of speed changing point upon irregularity of sliver after drafting.

The results are as follows:

(1) When the maximal moving distance of speed changing point is 0, the number of fiber ends in every increment remains unchanged, but the sliver thickness is reduced by the drafting action. Therefore, the coefficient of variation in the drafted sliver increases by the square root of the draft ratio.

(2) When the maximal moving distance of speed changing point is not 0, sliver irregularity vary with the increase in this distance. The increase ratio of sliver irregularity decreases with the increase of British count of sliver, fineness of fiber and staple fiber length. And the staple fiber length has the strongest influence on it. Furthermore, the coefficient of variation varies with the draft distribution and the moving condition of speed changing point on two drafting zones. It can be seen that there is an optimal draft distribution which makes the coefficient of variation minimum, and that the range of the first drafting ratio is about 1.5-3. When the distribution type of moving distance is the same one in each drafting zone, the difference between the maximal and the minimal value of coefficient of variation is the smallest one.

(3) It is also found that the correlation between the irregularity of the supplied sliver and the irregularity due to the movement of speed changing point is almost always a negative value on each drafting. On the first drafting and the second drafting in which the moving distance of speed changing point is 0, those correlations are regarded as independent of each other because of the small value (Max. −0.2). However, on the second drafting in which the moving distance of speed changing point is not 0, the correlation is not regarded as independent because of the large value (Max. −0.7).

1. Introduction

The changes of the sliver irregularity before and after drafting are reported by Cox[1], Foster[2], and Tabata and Ishikawa[3]. Almost all of them analyze sliver irregularity on the assumption which the irregularity made by drafting is independent of the irregularity of the supplied sliver. However, it may be considered that the draft irregularity depends on the distribution of speed changing point on the drafting zone. But, it is extremely difficult to measure the real form of this distribution. According to the reports of Ichino and Goto[4], Taylor[5], and Kawabata[6], it was said to be the exponential distribution or the biased normal distribution in which the mode was positioned near the front roller within the drafting zone.

In this paper, we attempt to simulate numerically how physical properties of fiber, sliver structure, and drafting condition affect thickness variation in the two-zone roller drafting. And then we analyze sliver irregularity related to before and after drafting.

This paper may be called as "Simulation of Two-Zone Roller Drafting Part II".

2. Assumption and Program[7]

2.1 Assumption for structure of sliver

It is assumed that a sliver consists of fiber with perfectly uniform staple length and fineness, that the fiber axis is parallel to the sliver axis, and that there are no hooked fibers in the sliver. When the sliver is divided into many minute increments of equal length along the sliver axis, every increment includes some numbers of fiber ends. However, it may be considered that the draft irregularity depends on the distribution of speed changing point on the drafting zone. But, it is extremely difficult to measure the real form of this distribution. According to the reports of Ichino and Goto[4], Taylor[5], and Kawabata[6], it was said to be the exponential distribution or the biased normal distribution in which the mode was positioned near the front roller within the drafting zone.

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\[ N_d = \frac{5,315}{N_e} \]

where \( N_e \) = British count of sliver (s)

\( N_d \) = denier count of sliver (d)

\( M \) = fineness of fiber (d)

\( L \) = staple fiber length (mm).

When the average number of fiber ends is given by the above equation, the number of fiber ends in each increment in a sliver is obtained by using the correspondence between the cumulative distribution function of the number of fiber ends and the uniform random numbers ranging in value from 0 to 1 and 0.5 on an average.

The number of fiber ends in the increment in doubled sliver is equal to the product of fiber ends in increment and the number of doubling.

### 2.3 Assumption for roller drafting

A draft ratio is defined by the ratio of the mean thickness of sliver before and after drafting. It is assumed that each roller gauge in this system is rightly set up corresponding to the staple fiber length, and that the moving speed of the fiber group is varied from the surface velocity of the back roller to that of the front roller at a point between the two rollers. The position is called the speed changing point. The speed changing point is distributed within the region bounded by a standard position suitably located near the front roller and another point a little away from the standard position toward the back roller. It is called the distribution of speed changing point. The location of speed changing point affects the movement of fiber group in the sliver. When the speed changing point is located at the standard position, the position of the fiber group in the drafted sliver remains unchanged. However, when the speed changing point moves away from the standard position toward the back roller, the position of the fiber group in the drafted sliver changes in the progressing direction.

Because the acceleration at this position takes place earlier than that at the standard position, the movement is in proportion to the distance from the standard position.

### 2.4 Program for roller drafting

As mentioned above, all fibers in increments are accelerated simultaneously to the surface speed of the front roller when the increment reaches the speed changing point. So, every increment in the sliver is given by the location of the speed changing point due to the distribution. While the fiber group which had been accelerated at the standard position moved by the distance \( m \), the fiber group which was accelerated at the position \( m \) moved by the distance of \( mZ \), where \( Z \) is the draft ratio. This results in a relative movement of \( m(Z-1) \) between the two fiber groups. When this quantity is divided by the length of increment \( ZW \) after drafting, the relative movement in terms of the number of increments is obtained.

### 3. Simulation Result and Discussion

The simulation was carried out on a Y.H.P 9825B personal computer.

#### 3.1 Produced sliver

In view of the computer memory restrictions, an increment length was 1 (mm) and the total number of increments was 1,000. So, the length of a sliver before drafting was 1,000 (mm).

The slivers were produced on the following condition: Individual fibers had the uniform fineness of 1, 1.7, 3, and 4 (d), and had the uniform staple length of 10, 20, 30, and 40 (mm). The British count of sliver was 0.1/8, 0.1/2, 0.1, 0.2, and 0.3 (s).

The distribution types of the number of fiber ends were the Poisson distribution for a random sliver and the

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Coefficient of variation of single sliver</th>
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<tbody>
<tr>
<td>Sliver</td>
<td>British count of sliver (s)</td>
</tr>
<tr>
<td></td>
<td>0.1/8</td>
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<td>Optional</td>
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(Fineness of fiber=1.7d. Staple fiber length=30mm)

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Coefficient of variation of doubled sliver</th>
</tr>
</thead>
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<tr>
<td>Sliver</td>
<td>Staple fiber length (mm)</td>
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</tr>
<tr>
<td>Random</td>
<td>0.0020</td>
</tr>
<tr>
<td>Optional</td>
<td>0.0045</td>
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</tbody>
</table>

(Fineness of fiber=1.7d, British count of sliver=0.1/8s)

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Coefficient of variation of doubled sliver</th>
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</thead>
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<tr>
<td>Sliver</td>
<td>Fineness of fiber (d)</td>
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<tr>
<td>Random</td>
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<tr>
<td>Optional</td>
<td>0.0044</td>
</tr>
</tbody>
</table>

(Staple fiber length=30mm, British count of sliver=0.1/8s)
normal distribution for a optional sliver. The number of doubling in a doubled sliver was 8.

Twenty-six kinds of slivers produced in this simulation are listed in Tables 1, 2, and 3.

### 3.2 Drafting condition

The system was the two-zone roller drafting in which the total draft ratio varying draft distribution between the drafting zones was 8. The maximal moving distance of the speed changing point was 0, 1, 2, and 3 (mm). The distribution types of speed changing point were the uniform, normal, and exponential.

Nine kinds of the moving distance of speed changing point produced are shown in Table 4.

### 3.3 Result and discussion

Figures 1 and 2 show the relation between draft distribution and coefficient of variation of the sliver obtained by the two draftings, in which the maximal moving distance and the distribution type of speed changing point are changed. But it was assumed that the same drafting condition was applied in the two-zone roller drafting.

It is found that the coefficient of variation in the drafted sliver varies with the maximal moving distance and the distribution type of speed changing point. That is to say, sliver irregularity decreases with the decrease of the maximal moving distance and the variance of speed changing point. Furthermore, when the maximal moving distance of speed changing point is not 0, the coefficient of variation in every drafted sliver has a minimal value at a certain draft distribution. Then, it is called the optimal draft distribution.

Figure 3 shows the mean increase ratio of the coefficient of variation in the drafted sliver. The increase ratio IRV of the coefficient of variation in the sliver obtained by the two-zone drafting is given by the following equations and the average value is called the mean increase ratio of the coefficient of variation:

\[
    IRV = \frac{V_{FF2} - V_s}{V_s}
\]

where \(V_{FF2}\) is the coefficient of variation in the sliver obtained by the two-zone drafting is given by the following equations and the average value is called the mean increase ratio of the coefficient of variation:

- \(V_{FF2}\) is the coefficient of variation in the sliver obtained by the two-zone drafting, in which the maximal moving distance of speed changing point is not 0 in each drafting zone.
- \(V_s\) is the coefficient of variation of the supplied sliver.

The mean increase ratio decreases with the increase of the staple fiber length, the fineness of fiber and the British count of sliver.
count of the sliver. And staple fiber length has the strongest influence on mean increase ratio. Furthermore, it is observed that mean increase ratio in random sliver is about twice as high as that in optional sliver. Therefore, it is difficult for us to increase irregularity of optional sliver in amount by drafting.

Next, paying attention to optimal draft distribution, we investigate the effect of staple fiber length and draft condition influencing on draft irregularity. Tables 5 and 6 show the changes of optimal draft distribution on various drafting conditions. Optimal draft distribution hardly causes any change by staple fiber length except for the drafting conditions in which the speed changing points have the maximal moving distance of 2 or 3 (mm), and have the uniform or normal distribution. The first draft ratio of the optimal draft distribution decreases with the variance of the moving distance of speed changing point in the first drafting zone becomes larger than that in the second drafting zone. However, the first draft ratio of optimal draft distribution is up to 1.5–3 in all the cases simulated. In general, this is an acceptable fact.

![Fig. 3 Mean increase ratio of coefficient of variation on draft distribution. (○: Random sliver, ●: Optional sliver, Distribution type of moving distance = uniform, Maximal moving distance of speed changing point in each zone = 3 (mm), (a) British count of sliver = 0.1/8 (s), Fineness of fiber = 1.7 (d), (b) British count of sliver = 0.1/8 (s), Staple fiber length = 30 (mm), (c) Fineness of fiber = 1.7 (d), Staple fiber length = 30 (mm))](image)

<table>
<thead>
<tr>
<th>Table 5</th>
<th>Change of optimal draft distribution on the same drafting condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distriton type and maxial moving distance of speed changing point in each drafting zone</td>
<td>Optical draft distribution (Z1×Z2)</td>
</tr>
<tr>
<td></td>
<td>Staple fiber length (mm)</td>
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<td>Uniform</td>
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<tr>
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<tr>
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<tr>
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<td>2</td>
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<tr>
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<td>1</td>
</tr>
<tr>
<td>Exponential</td>
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<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
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(Random and optional slivers, British count of sliver=0.1/8(s), Fineness of fiber=1.7(d))

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Change of optimal draft distribution on different drafting condition</th>
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<tbody>
<tr>
<td>Distribution type and maximal moving distance of speed changing point</td>
<td>Optical draft distribution (Z1×Z2)</td>
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<tr>
<td>1st drafting zone</td>
<td>2nd drafting zone</td>
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<tr>
<td>Uniform</td>
<td>2 (mm)</td>
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<td></td>
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<td>Normal</td>
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<td>Exponential</td>
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<td>2</td>
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<td>2</td>
</tr>
<tr>
<td>Uniform</td>
<td>1</td>
</tr>
<tr>
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</tbody>
</table>

(Random and optional slivers, British count of sliver=0.1/8(s), Fineness of fiber=1.7(d), Staple fiber length=30(mm))
Figures 4, 5 and 6 show the relation between the coefficient of variation in the drafted sliver and the draft distribution. When the maximal moving distance of speed changing point in each drafting zone is 2(mm), the difference between the maximal and the minimal values of coefficient of variation in the drafted sliver decreases with the decrease of the variance of moving distance of speed changing point on two drafting zones. In the case of drafting in which each zone has the same distribution type of speed changing point, the results are as follows: When the maximal moving distance of speed changing point in the first drafting zone is larger than that in the second drafting zone, the difference between the maximal and the minimal values of coefficient of variation in the sliver decreases, while the difference between the coefficients of variation near the optimal draft distribution increases. On the contrary, when the maximal moving distance of speed changing point in the first drafting zone is smaller than that in the second drafting zone, the coefficient of variation in the sliver obtained by optimal draft distribution is smaller than that in the above case, and the difference between the coefficients of variation near the optimal draft distribution decreases. However, the first draft ratio of the optimal draft distribution increases.

Fig. 4 Comparison with different distribution types of moving distance in each drafting zone. (Random sliver, British count of sliver = 0.1/8(s), Fineness of fiber = 1.7(d), Staple fiber length = 20(mm), Maximal moving distance of speed changing point in each zone = 2 (mm))

Fig. 5 Comparison with different maximal moving distance of speed changing point in each drafting zone. (Random sliver, British count of sliver = 0.1/8(s), Fineness of fiber = 1.7(d), Staple fiber length = 20(mm), Total maximal moving distance of speed changing point in two zones = 3 (mm))
As mentioned above, the coefficient of variation in the drafted sliver varies with the maximal moving distance, the distribution type and the variance of speed changing point in each drafting zone. However, as the difference between the variances of speed changing point in each drafting zone becomes smaller even if the distribution type of speed changing point in each drafting zone is the same one, the difference between the maximal and the minimal values of the coefficient of variation in the drafted sliver and the minimal value obtained by the optimal draft distribution decrease. This fact results from increasing the irregularity made by the movement of speed changing point. Namely, when the bigger draft ratio is chosen, the worse draft irregularity is product on the basis of the fixed total draft ratio.

Figures 7 and 8 show relation between the coefficient of variation in the sliver made by every drafting and the distribution of draft ratio. In graphs, each suffix refers to the value as follows:

- **S** = supplied sliver,
- **P** = drafting in which the maximal moving distance of speed changing point is 0,
- **F'** = drafting in which the maximal moving distance of speed changing point is not 0,
- **1** = the first drafting, and **2** = the second drafting.

Therefore,

- **VP1** = the first drafting in which the draft ratio is \( Z_1 \) and the maximal moving distance of speed changing point is 0,
- **VFP1** = the first drafting in which the draft ratio is \( Z_1 \) and the maximal moving distance of speed changing point is not 0,
- **VPP2** = the second drafting after \( V_{P1} \), in which the draft ratio is \( Z_2 \) and the maximal moving distance of speed changing point is 0,
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- **VPF2** = the second drafting after \( V_{PF1} \), in which the draft ratio is \( Z_2 \) and the maximal moving distance of speed changing point is 0,
- **VFF2** = the second drafting after \( V_{FF1} \), in which the draft ratio is \( Z_2 \) and the maximal moving distance of speed changing point is not 0.

The coefficient of variation in the sliver made by the first drafting, namely, \( V_{P1} \) and \( V_{F1} \), increase with the increase of the first draft ratio. However, the coefficient of variation in the sliver made by the second drafting varies with the draft condition. That is to say, in proportion to the decrease of the second draft ratio because of the fixed total draft ratio, \( V_{PP2} \) becomes constant, \( V_{PF2} \) decreases, \( V_{FP2} \) increases and \( V_{FF2} \) comes to have a minimal value at a certain draft distribution.

We tried calculating theoretically the coefficient of variation in the sliver produced by every drafting. From the assumption mentioned above, the average number \( H \) of fibers in the sliver cross section is given by:

\[ F = \text{drafting in which the maximal moving distance of speed changing point is not 0}, \]
\[ 1 = \text{the first drafting, and 2 = the second drafting}. \]
\( H = \frac{N_d}{M} \)

where \( N_d \) is the denier count of sliver (d), and \( M \) is the fineness of fiber (d).

Furthermore, it is well-known that the coefficient of variation \( V_r \) in the random sliver is \( 1/\sqrt{H} \). By substituting \( H \) above, we get: \( V_r = \sqrt{M/N_d} \)

Therefore, the coefficient of variation in the drafted sliver is given by:

1. In the case of drafting in which the maximal moving distance of speed changing point is 0, the number of fiber ends in every increment \( W \) in length remains unchanged and the increment length increases to \( ZW \) where \( Z \) is the draft ratio.

Then, the denier count \( D \) and the coefficient of variation \( V_P \) of the drafted sliver are given by:

\[ D = \frac{N_d}{Z} \]
\[ V_P = \sqrt{M/D} \]

By combining them, we get: \( V_P = \sqrt{MZ/N_d} = V_r \times \sqrt{Z} \)

Therefore, \( V_{P1} \) increases with the increase of the first draft ratio. But \( V_{P2} \) is constant because of the fixed total draft ratio.

2. In the case of the drafting in which the maximal moving distance of speed changing point is not 0, the number of fiber ends in the increment varies with the movement of speed changing point. Then, the draft irregularity is added to the supplied sliver. However, the changes of \( V_{F1}, V_{PF2}, V_{PF2}, \) and \( V_{F2} \) cannot be expressed by the explanation above only. Therefore, it may be considered that irregularity made by drafting is given by the following equation:

\[
(\text{Irregularity of sliver after drafting}) = (\text{Irregularity made by drafting in which speed changing point does not move}) + (\text{Irregularity made by the movement of speed changing point}) + \beta
\]

where \( \beta \) is the value given by the relation between irregularity of supplied sliver and irregularity made by movement of speed changing point. Then, if the relation is independent of each other, \( \beta = 0 \). And if the relation is not independent, \( \beta \neq 0 \).

Figures 9 and 10 show the values obtained by the two relation between irregularity of supplied sliver and irregularity made by movement of speed changing point. Figures 9 and 10 show the values obtained by the two draftings in which the maximal moving distance of speed changing point is not 0. Because the coefficients of correlation with \( V_{F1} \) and \( V_{PP2} \) are from about \(-0.2\) to \(0.2\), it may be considered that the two irregularities have no relation each other. However, because the coefficient of correlation with \( F_{PP2} \) is about \(-0.5\), it cannot be considered that the two irregularities have no relation. In the comparison between the random sliver and the optional sliver, the coefficients of correlation with \( V_{F1} \) and \( V_{PP2} \) in the latter are smaller than that in the former, but the coefficient of correlation with \( V_{PP2} \) is about the same value in both slivers. Figs 11 and 12 show the coefficient of correlation with \( V_{PP2} \). The coefficient of correlation with \( V_{PP2} \) decreases with the maximal moving distance and distribution type of speed changing point. Therefore, the two irregularities above have a relation.

As mentioned above, the relation between the irregularity of supplied sliver and that made by movement
of speed changing point shows almost always a negative value on each drafting. On the first and the second drafting in which the moving distance of speed changing point is 0, correlation is regarded as independent of each other. However, on the two draftings in which the maximal moving distance of speed changing point is not 0, the correlation is not regarded as independent of each other.

By this result, we obtained the experiential equations to be used in the calculation of coefficient of variation in the drafted sliver as follows:

1. On the first drafting
   (A) When the maximal moving distance of speed changing point is 0,
   \[ V_{Pj}^2 = V_i \times Z_1 \]
   (B) When the maximal moving distance of speed changing point is not 0,
   \[ V_{Fi}^2 = V_{Pj}^2 + B(Z_1 - 1)^2 \]
   where \( B \) is the value given by the staple fiber length and the moving condition of speed changing point in the first drafting.

2. On the second drafting
   (A) When the maximal moving distance of speed changing point is 0 and the first drafting has the following conditions:
      (a) The maximal moving distance of speed changing point is 0,
      \[ V_{Pj}^2 = V_{Pj}^2 \times Z_2 = V_i \times Z \]
      where \( Z \) is the total draft ratio. (= \( Z_1 \times Z_2 \))
      (b) The maximal moving distance of speed changing point is not 0,
      \[ V_{Fi}^2 = V_{Fi}^2 \times Z_2. \]
   (B) When the maximal moving distance of speed changing point is not 0 and the first drafting has the following conditions:
      (a) The maximal moving distance of speed changing point is 0,
      \[ V_{PPj}^2 = V_{PPj}^2 + E(Z_2 - 1)^2 \]
      where \( E \) is the value given by the staple fiber length and the moving condition of speed changing point in the second drafting.
      (b) The maximal moving distance of speed changing point is not 0,
      \[ V_{FFi}^2 = V_{FFi}^2 + E(Z_2 - 1)^2 + \beta \]
      where \( \beta \) is the value given by the correlation between irregularity of the supplied sliver and that made by movement of speed changing point.

3. The coefficients \( B \) and \( E \)
   It is assumed that the coefficients \( B \) and \( E \) vary with the staple fiber length \( L \) of the supplied sliver, and the maximal moving distance \( J \), the distribution type and the variance \( \sigma_j^2 \) of speed changing point in the drafting zone. If the movement of speed changing point in each drafting zone is on the same condition, \( B = E \). And if the movement of speed changing point in each drafting zone is on the different condition, \( B \neq E \).
   \[ B \text{ or } E = (F/L^2 + G/YL) \times \sigma_j^2 \]
   where \( F = 0.388 \) and \( G = 0.0839 \) in the case of the uniform distribution,
   \[ F = 1.046 \text{ and } G = 0.0223 \text{ in the case of the normal distribution}, \]
   \[ F = 1.059 \text{ and } G = 0.0609 \text{ in the case of the exponential distribution}. \]
   Figures 13 and 14 show the coefficient of variation in the random and the optional sliver calculated by using the above equations. The result of the simulation is shown in Figures 7 and 8.
Fig. 13 Calculated values of coefficient of variation in every drafting (Compare with Fig. 7. Random sliver, British count of sliver = 0.1/8(s), Fineness of fiber = 1.7(d), Staple fiber length = 30(mm), Maximal moving distance of speed changing point = 3 (mm), Distribution type of moving distance = uniform)

Fig. 14 Calculated values of coefficient of variation in every drafting (Compare with Fig. 8. Optional sliver, British count of sliver = 0.1/8(s), Fineness of fiber = 1.7(d), Staple fiber length = 30(mm), Maximal moving distance of speed changing point = 3 (mm), Distribution type of moving distance = uniform)

Literature Cited

[4] Ichino, and Goto; Sen-i Gakkaishi, 12, 6 (1956).