Experimental Dual-Roller Carding Machine

Part 2: Blending Performance of Fibers Fed from Two Feeding Zones

By Shigeru Nishikawa and Tatusya Kawakami, Members, TMSJ

*The Textile Research Institute of the Japanese Government, Yokohama


Abstract

The dual carding system discussed here consists of two feeding zones and two carding zones around a cylinder. Feed the same type of fiber in equal quantities through the two feeding zones. Fix the diameter, r.p.m., settings and metallic wire of the taker-in rollers, workers and doffers in both carding zones under the same conditions. In this case, the ratio of blending, in the slivers, of fibers fed through the two feeding zones are obtainable as follows:

\[ \frac{Q_0_1}{Q_0_1'Q_0_2'/Q_0_1=k:k'(1-k)} \]

where

- \( Q_0_1 \): Weight (g/cm) of slivers delivered through doffer \((d_0_1)\) on which fibers are fed through the two feeding zones \(f_1\) and \(f_2\).
- \( q_1_0 \): Weight (g/cm) of sliver delivered through doffer \((d_0_1)\) on which fibers are fed through the feeding zone \(f_1\).
- \( q_0_2' \): Weight (g/cm) of sliver delivered through doffer \((d_0_1)\) on which fibers are fed through the feeding zone \(f_2\).
- \( k \): Ratio of transfer from cylinder to doffer \((d_0_1)\) of the fibers fed through feeding zone \(f_1\).
- \( k' \): Ratio of transfer from cylinder to doffer \((d_0_1)\) of the fibers fed through feeding zone \(f_2\).

The blending ratio obtained experimentally, about 6:4, is explained by a difference in quantity between the fibers fed through the two feeding zones and differences in opening conditions at the point where fibers transfer from the cylinder to the doffer. The author believes that opening by the workers has to be improved to make the blending ratio 5:5 or bring it close to this figure.

KEY WORDS: CARDS, CARDING, CARD CYLINDER, LICKER-IN, CARD DOFFER, CARDING EFFICIENCY, SYNTHETIC FIBERS, PRODUCTION, FEED ROLLS, WORKERS, STRIPPERS SLIVERS, METALLIC CARD CLOTHING, DOFFER COMBS

1. Introduction

The previous article compared, in performance level, our dual carding system, experimentally built, with the conventional type under the same mechanical conditions. The experiment showed that it was possible to double production by our dual carding system without lowering the quality of slivers.

The dual carding system has a cylinder, two feeding parts and two doffers. This means that laps fed into the two feeding parts pass through the two doffers, and are converted into two slivers. Fibers in lap placed in one feeding part are blended into one sliver. There are two feeding parts, one lap in each. The fibers in each lap are blended into one separate sliver. The slivers are influenced by the unevenness of the laps. Consequently, the slivers in the two feeding parts have the same character of unevenness. In other words, the dual carding system has special functions to level off the unevenness of laps in the two feeding parts.
The present article looks experimentally into the difference in the manner of transfer, from the cylinder surface to the two doffers, of fibers fed through one feeding part.

2. Characteristics of the Dual Carding System

To analyze the basic characteristics of our dual carding system, let us first consider a carding system without workers. The relation between fed laps and delivered slivers is as shown in Fig. 1. Divide the total surface of the cylinder into two parts. The upper part corresponds to the flow of fibers from Q₁₁ to d₀₁. The lower part corresponds to the flow from Q₁₂ to d₀₂. The laps are 20 cm in width. Q₁₁, Q₁₂: Weight (g/cm) of laps in feeding zones fₑ₁ and fₑ₂.

q₀₁, q₀₂: Weight (g/cm) of slivers delivered from doffers d₀₁ and d₀₂.

Q₀₁, Q₀₂: Weight (g/cm) of slivers delivered from doffers d₀₁ and d₀₂.

Q₀₁, Q₀₂: Weight (g/cm) of slivers delivered through doffer d₀₁ on which Q₁₁ and Q₁₂ are fed through the two feeding zones fₑ₁ and fₑ₂.

q₀₁, q₀₂: Weight (g/cm) of slivers delivered through doffer d₀₂ on which Q₁₂ and Q₁₁ are fed through the two feeding zones fₑ₂ and fₑ₁.

θₑ₁, θₑ₂: Fibers depositing in upper and lower parts of the cylinder (g/cm)

θₑ₁, θₑ₂: Fibers depositing in upper part of the cylinder on which Q₁₁ and Q₁₂ are fed through the two feeding zones (g/cm)

θₑ₁, θₑ₂: Fibers depositing in lower part of the cylinder on which Q₁₂ and Q₁₁ are fed through the two feeding zones (g/cm)

θ₀₁, θ₀₂: Fibers depositing on surfaces of doffers d₀₁ and d₀₂ (g/cm)

Vₑ₁, Vₑ₂: Speed (cm/min) of feed lattices fₑ₁ and fₑ₂

Vₑ: Surface speed (cm/min) of the cylinder

V₀₁, V₀₂: Surface speed (cm/min) of doffers d₀₁ and d₀₂

A.: Circumference (cm) of the cylinder

K₁, K₂: Ratio of transfer of fibers to doffers d₀₁ and d₀₂ when they are θₑ₁ and θₑ₂ on the cylinder.

K₁ = \frac{θ₀₁·Vₑ₁}{θₑ₁·Vₑ}, \quad K₂ = \frac{θ₀₂·Vₑ₂}{θₑ₂·Vₑ}

k₁, k₂: Ratio of transfer of fibers to doffer d₀₁ when they are θₑ₁ and θₑ₂ in the upper part of the cylinder

k₁, k₂: Ratio of transfer of fibers to doffer d₀₂ when they are θₑ₁ and θₑ₂ in the lower part of the cylinder

k₁, k₂: Ratio of transfer of fibers to doffer d₀₁ when they are θ₀₁ and θ₀₂ in the upper part of the cylinder

k₁, k₂: Ratio of transfer of fibers to doffer d₀₂ when they are θ₀₁ and θ₀₂ in the lower part of the cylinder

θ₀₁ = \frac{Vₑ·Q₁₁}{kₙ₁·kₚ₁·(1-kₚ₁)} (1-e^{-T₁}) \quad \cdots \cdots (2')

θ₀₂ = \frac{Vₑ·Q₁₂}{kₙ₂·kₚ₂·(1-kₚ₂)} (1-e^{-T₂}) \quad \cdots \cdots (3')

T₁ = \frac{Vₑ·kₚ₁·(1-kₚ₁)}{kₙ₁·kₚ₂·kₚ₁·(1-kₚ₂)} A₁

T₂ = \frac{Vₑ·kₚ₂·(1-kₚ₂)}{kₙ₂·kₚ₁·kₚ₂·(1-kₚ₁)} A₂

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Carding system $Q_{i1};Q_{i2} \rightarrow Q_{o1};Q_{o2}$ is actually carding system $Q_{i2}$ to $Q_{o1};Q_{o2}$ with another fed lap added. Slivers delivered from doffer $d_{o1}$ by this system are expressible as the sum of (3) and (4). The characteristics of this carding system are expressible, assuming as follows: $k_1 = k_2 = k$, $k'_1 = k'_2 = k'$. 

$$V_{d1} (q_{o1} + q_{o2}') = \frac{V_{f1} Q_{o1} k + V_{f2} Q_{o2} (1-k) k'}{k + k' (1-k)} \left(1 - e^{-t} \right) \quad (5)$$

For doffer $d_{o2}$,

$$V_{d2} (q_{o1} + q_{o1}') = \frac{V_{f1} Q_{o1} k + V_{f2} Q_{o2} (1-k) k'}{k + k' (1-k)} \left(1 - e^{-t} \right) \quad (5)'$$

is obtainable. 

Assuming $V_{f1} = V_{f2}$, $Q_{i1} = Q_{i2}$, $V_{d1} = V_{d2}$, the slivers delivered from each doffers are expressible as follows:

output = input $\left(1 - e^{-t/T} \right)$

This means that our dual carding system is essentially equal in characteristics to a conventional carding system.

The blending performance level of our dual carding system is expressible by the ratio of fed lap $Q_{i1}$ included in sliver $Q_{o1}$ delivered from doffer $d_{o1}$, which ratio is expressible as follows:

$$\frac{q_{o1}}{Q_{o1}} = \frac{k}{k + (1-k) k'} \quad (6)$$

The ratio of $Q_{i2}$ included in sliver $Q_{o1}$ can be shown as follows:

$$\frac{q_{o2}'}{Q_{o1}} = \frac{(1-k) k'}{k + (1-k) k'} \quad (6)'$$

Especially, assuming $k = k' = K$, the preceding expression can be transformed into:

$$\frac{1}{2-K}, \frac{1-K}{2-K},$$

showing that fibers fed through the two feeding zones can be blended better by reducing the ratio of transfer of fibers.

3. Ratio of Distribution of One Fed Lap When the Carding System Has Two Doffers

3-1. Experiments

In our experiments with carding system, $Q_{i1};Q_{i2} \rightarrow Q_{o1}$, we used Viscose fiber laps (1.5 den, 2 1/4 in cut, 20 cm width). Laps fed through one of the two feeding parts were coloured for identification.

The blending ratio of the fibers in each of two slivers was measured with an Electro-Photo Reflex meter which has a detection diameter of 25 mm. The results of measurement were corrected by a correction curve experimentally made beforehand. Fibers (about 0.2 g) to be measure were collected from the slivers.

Table 1 shows the mechanical conditions of the carding machine during the experiments. A mechanism symmetrical to the shaft of the cylinder was fixed under the same

<table>
<thead>
<tr>
<th>Name</th>
<th>Diameter (mm)</th>
<th>Revolutions (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder</td>
<td>510</td>
<td>90</td>
</tr>
<tr>
<td>Doffer</td>
<td>260</td>
<td>6</td>
</tr>
<tr>
<td>Worker</td>
<td>107</td>
<td>6</td>
</tr>
<tr>
<td>1st taker-in</td>
<td>85</td>
<td>93</td>
</tr>
<tr>
<td>2nd taker-in</td>
<td>85</td>
<td>186</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Diameter (mm)</th>
<th>Revolutions (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder-Doffer</td>
<td>6/1000</td>
<td></td>
</tr>
<tr>
<td>Cylinder-1st Worker</td>
<td>7/1000</td>
<td></td>
</tr>
<tr>
<td>Cylinder-2nd Worker</td>
<td>5/1000</td>
<td></td>
</tr>
</tbody>
</table>

(Metallic wire was used)
conditions, and laps fed into the feeding zones were the same in quantity. Fibers for measurement on the rollers were collected by abruptly stopping the carding machine after it reached stationary state.

### Table 2 Distribution Ratio of Fibers Fed from One Feeding Part into Each Sliver

<table>
<thead>
<tr>
<th>Q1 Q2 → Q1Q02</th>
<th>Q1 → q01q01'</th>
</tr>
</thead>
<tbody>
<tr>
<td>q01</td>
<td>q01'</td>
</tr>
<tr>
<td>Without workers</td>
<td>67</td>
</tr>
<tr>
<td>With 2 workers</td>
<td>62</td>
</tr>
</tbody>
</table>

3-2. Relation between Condition of Opening of Fibers Depositing on Cylinder and Fiber Distribution to Two Doffers

With the aid of carding systems, Q1 → q01q01' and Q1 Q2 → Q0Q0, we observed the process of distribution of fibers in different quantities to two doffers. Figs. 2 and 3 show fibers depositing on the cylinder and give the ratio of transfer of fibers to the doffer while laps were fed increasingly, the carding system having no worker at one time and at another time, two workers each in the upper and lower parts of the cylinder at another time.

The ratio of distribution of fibers into two slivers when a lap was fed from one feeding zone (f01) is given in Table 2. The ratio of the weight of two slivers delivered over a three-minute period in carding system Q1→q01q01' is also shown in the same table.

In this system, the first fed lap Q1 transferred to the cylinder surface is carded by the two doffers before returning to the feeding point. Therefore, the fibers on the cylinder surface after passing the point of action by each doffer decrease, respectively, from \( \theta_{c1} \) to \( \theta_{c1}(1-k_1) \) and from \( \theta_{c2}(=\theta_{c1}(1-k_1)) \) to \( \theta_{c2}(1-k_1'). \)

Our experiments showed that, even when the two doffers were fixed under the same mechanical conditions, doffer d01 received far larger quantities than doffer d02 when fibers transferred into each doffer were compared in quantity. This was particularly the case when there were no workers.

This showing was presumably traceable to the condition of opening of the fibers on the cylinder. Fibers reaching the entrance to the first doffer, d01, when the doffer had no carding by workers included some unopen fibers fed from the taker-in roller and, therefore, looked as if they hung over the surface of the cylinder’s metallic wires. In such a case, fibers on the cylinder are transferred in relatively large quantities to the doffer.

On the other hand, the fibers on the cylinder after passing the carding point of doffer, sank between the cylinder’s metallic wires and many of them were open. Therefore, fewer fibers were transferred to doffer d02 than to doffer d01. Hence a distinct difference in quantity was noticed between the slivers delivered from the two doffers. When there was carding by workers in both the upper and lower parts of the cylinder, there were hardly any unopen fibers, and the slivers delivered from the two doffers were nearly equal in quantity because the fibers in the upper and lower parts of the cylinder were in about the same condition of opening.

The quantity of fibers in the upper part of the cylinder in carding system Q1 Q2 → Q0Q0 was essentially the sum of \( \theta_{c1} \) in carding system Q1 → q01q01' and \( \theta_{c2}' \) in carding system Q2 → q01q01'. However, the fibers on the cylinder in carding system Q1 Q2 → Q0Q0 exceeded in quantity the total of \( \theta_{c1} \) and \( \theta_{c2}' \) obtained only by carding system
in carding system \( Q_{1}-\rightarrow q_{01}q_{01}' \) was equal to \( \theta_{e1} \) in carding system \( Q_{1}-\rightarrow q_{01}q_{01}' \), because both systems were fixed the same in mechanical conditions and in the amount of lap-feeding.

The conceivable reason for this quantitative showing is that, with another feeding zone added to carding system \( Q_{1}-\rightarrow q_{01}q_{01}' \), variations occurred in the degree of inter-fiber contact and of anti-air resistance, thus reducing the transfer ratio \( k, k' \). The curves \( k \) and \( k' \) in Figs. 2 and 3 illustrate the ratio of transfer fibers (\( \theta_{e1}, \theta_{e2} \)) on the cylinder to the doffer. The solid lines are for carding system \( Q_{1}Q_{12}-\rightarrow Q_{01}Q_{02} \) and the dotted lines for carding system \( Q_{1}-\rightarrow q_{01}q_{01}' \). The values \( k \) and \( k' \) for carding system \( Q_{1}Q_{12}-\rightarrow Q_{01}Q_{02} \) were obtained by this method:

Stop the carding machine abruptly when it reaches stationary state. Collect samples from fibers on the cylinder and the doffer. Weigh the samples and measure their blending ratio with an electro-photo reflect meter. Then calculate the values \( k \) and \( k' \) from the values \( \theta_{e1}, \theta_{e2} \) obtained from the weight and the blending ratio of each sample. (\( \theta_{e1} \) and \( \theta_{e2} \) are fiber weights \( Q_{11} \) and \( Q_{12} \) included in the fibers on the doffer \( d_{01} \)).

Table 3 Ratio of Fiber Transfer from Cylinder to Workers

<table>
<thead>
<tr>
<th>Containing</th>
<th>Transfer</th>
<th>Ratio of Fiber Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st worker ( (w_{01}) )</td>
<td>82</td>
<td>( K_{w} ) 0.080</td>
</tr>
<tr>
<td>2nd worker ( (w_{02}) )</td>
<td>67</td>
<td>( K_{w} ) 0.057</td>
</tr>
<tr>
<td>Silver ( (Q_{01}) )</td>
<td>62</td>
<td></td>
</tr>
</tbody>
</table>

Amount of fibers on cylinder: \( 6 \times 10^{-2} g/1 \div 20 \) cm when \( Q_{1}Q_{12}-\rightarrow Q_{01}Q_{02} \) and \( Q_{1}-\rightarrow q_{01}q_{01}' \).

The method was based on the assumption that the amount \( \theta_{e} \) of fibers on the cylinder consists of circulating fibers \( \theta_{e} \) and fibers \( \theta_{e} \) fed from the taker-in roller (lap \( Q_{11} \)); and that \( \theta_{e1} \) is the aggregate amount of fibers \( \theta_{e} \) and \( Q_{11} \) constituting \( \theta_{e} \).

The value \( k_{1} \) for carding system \( Q_{1}Q_{12}-\rightarrow Q_{01}Q_{02} \) was almost the same as for carding system \( Q_{1}-\rightarrow q_{01}q_{01}' \) when the amount of fibers on the cylinder was the same for each carding system. However, the fibers on the cylinder in carding system \( Q_{1}Q_{12}-\rightarrow Q_{01}Q_{02} \) being covered with fibers \( \theta_{e} \) fed from the taker-in roller, were difficult of transfer to the doffer. Therefore, carding systems \( Q_{1}Q_{12}-\rightarrow Q_{01}Q_{02} \) and \( Q_{1}-\rightarrow q_{01}q_{01}' \) differed in the ratio of transfer of fibers into the two doffers.

This difference, it seems safe to believe, is traceable to the condition of opening of fibers depositing on the cylinder.

For example, if fibers on the cylinder could be opened in adequate degree, such as \( k_{1}=k_{2}' \), fibers transferred to the two doffers would be brought closer to equality in amount by the rate of \( \theta_{e1} \): \( \theta_{e1}(1-k_{1}) \).

3-3. How Good is Blending of Fibers Fed from Two Feeding Zones by Carding by Workers

The function workers are essentially the opening and blending of fibers in fed laps and straightening out of fibers on the cylinder. The roller carding machine is particularly good for the blending of fibers in fed laps. The ability of a carding machine to blend fibers according to the feeding direction is evaluated by what is called “correcting power” [3].

We are concerned here with blending by a carding system which has two feeding zones and a doffer. Table 3 gives the rates of fibers depositing on the 1st and 2nd workers in carding system \( Q_{1}Q_{12}-\rightarrow Q_{01}Q_{02} \); the ratio of \( Q_{1} \) included in circulating fibers \( \theta_{e} \); and the transfer ratios \( K_{w} \) and \( K_{w} \) for the 1st and 2nd workers in carding systems \( Q_{1}Q_{12}-\rightarrow Q_{01}Q_{02} \) and \( Q_{1}-\rightarrow q_{01}q_{01}' \).

\[
K_{w} = \frac{\theta_{e} V_{w}}{\theta_{e} V_{w} - \theta_{e} V_{w}},
\]

\[
K_{w} = \frac{\theta_{e} V_{w}}{\theta_{e} V_{w} - \theta_{e} V_{w}}.
\]

where \( \theta_{e} V_{w} \) and \( \theta_{e} V_{w} \) are the percentages of the fibers transferred into the 1st and 2nd workers per unit time.
entrance of the 2nd worker, excluding the fibers
delivered from Or into the 1st worker.

\( K_{wt} \): Ratio of transfer of \( \theta_r \) to the 2nd worker.
\( K_{wr} \): Ratio of transfer of \( \theta_r \) to the 1st worker.

\( \theta_r \): amount of fibers in \( \theta_r \) carried directly to the
entrance to the 2nd worker, excluding the fibers
delivered from \( \theta_r \) into the 1st worker.

\( K_{wr} \): Ratio of transfer of \( \theta_r \) to the 2nd worker.
\( K_{ww} \): Ratio of fibers which stay put in the 1st worker.
\( K_{wtw} \): Ratio of fibers transferred from the 1st to the 2nd
worker through the cylinder.

The values of \( K_{wt} \) and \( K_{wtw} \) were obtained by feeding
about 1 g of tracer fibers to the carding machine during
normal-state operation and by weighing the tracer fibers
depositing on 1st and 2nd workers. The values thus ob-
tained were:

\[ K_{wt} = 0.45 \quad K_{wtw} = 0.30 \]

Since the setting of the 1st worker was made as wide as
7/1000 in to prevent damage to fibers, most of \( \theta_r \) in the
outer layer on the cylinder were transferred to the 1st
worker \((K_{wt} = 0.45)\) but hardly any of the fibers in the inner
layer were.

Presumably, carding by the 1st worker did only slight
blending to \( Q_{11} \) and \( Q_{12} \). The rate of fibers \( Q_{11} \) in \( \theta_r \) was
82 %. The tracer fibers reaching the entrance to the 2nd
worker directly from \( \theta_r \) and indirectly from the 1st
worker had been opened more or less by carding by the 1st
worker and the fibers transferred to the 2nd worker de-
creased in amount, resulting in a slightly better rate of
blending. The rate of fibers \( Q_{11} \) was 67 %.

Fig. 5 gives the ratio \( K \) of transfer to the doffer, the rate
of \( Q_{12} \) included in sliver \( Q_{02} \), and CV (% of unevenness
of blending of \( Q_{11} \) in sliver \( Q_{01} \) plotted to the ratio of
transfer of fibers to the workers which means the degree of
carding by the workers. The ratio of transfer on a carding
system using 1st and 2nd workers used was obtained
from the sum of the ratio of fibers transferred to both
workers.

The figure indicates an almost linear relation between
variables. Presumably, then, it is possible to estimate the
degree of blending of fibers fed through two feeding zones
on a dual carding system from the degree of carding by the
workers.

All this suggests that workers had better be installed in
such a way as to permit carding in the widest possible range
so that laps could be fed more evenly into two slivers.

3-4. Unevenness of Laps Fed From Two Feeding Zones
and Unevenness Characteristics Showing in Two
Slivers

Since laps fed from two feeding zones are delivered into
two slivers in the ratios given in eqs. (6) and (6)', uneven-
nesses of both slivers are almost the same in characteristics.

The USTER evenness charts given in Fig. 6 are for slivers
\( Q_{01} \) and \( Q_{02} \) delivered under the following conditions:

The velocity of lattice \( f_1 \) was a constant \( V_{f1} = 13.5 \text{ cm/min} \)
and that of lattice \( f_2 \) sinusoidal

\[ V_{f2} + V_{f2} \sin \omega t, \]
where \( V_{f2} = 13.5 \text{ cm/min}; V_{f2} = 6.0 \text{ cm/min} \).
The weight of laps was 1.3 g/cm in both feeding zones.

As shown in Fig. 6, unevenness in \( Q_{12} \) given by feed
lattice \( f_2 \) showed with similar characteristics in both
slivers despite a drop in amplitude gain. The figure es-
tablishes that the mean of amplitudes over 5 periods is
\( \pm 12\% \) in the chart on \( Q_{01} \) sliver and \( \pm 16\% \) in the chart
on \( Q_{02} \) sliver; and that, therefore, the ratio of \( Q_{01} \) to
\( Q_{02} \) is 4:6.
4. Conclusions

In our dual roller carding system, the ratio of blending, in a delivered sliver, of fibers fed from the two feeding zones is determined by the zone-by-zone ratios of fibers transferred from the cylinder to the entrance to the doffer and by the zone-by-zone ratios of transfer to the doffer.

The blending ratio obtained by our experimental model was about 6:4. The unequal ratio presumably resulted mainly from variations in the degree of opening of fibers depositing on the cylinder. In other words, the poorer the opening of fibers on the cylinder, the larger the inter-zonal difference in the amount of fibers depositing on the cylinder and the inter-zonal difference in the ratio of transfer to the doffer.

It is believed, therefore, that a higher degree of opening by the workers would help make the blending ratio 5:5.

Literature cited