Development of Continuous Rope Scouring Machinery
“RSC” and Technology

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Abstract

Continuous reciprocal scouring machine (RSC) is a unique machine to which reciprocal mechanism is adopted and operation made more efficient, making use of same squeezing effect of the rope scouring machine.

With comparatively small floor space, high performance with high efficiency and perfectly continuous wet finishing processes of wool fabric from feeding to drying are realized by this machine. Scouring cost is reduced to about half of that of the conventional batch type, saving such energy as water, electricity and steam.

1. Introduction

The continuous rope scouring machinery “RSC” is a machine originally developed by Toyobo Co., for wool finishing through the research and development for as many as ten years.

Finishing processes for wool fabrics are troublesome because of their complication and wide range, and the modernization of finishing machinery is rather behind that for cotton and synthetic fiber fabrics. RSC, completed after many improvements through its commercial operation, has solved such problems and is believed to rationalize the wool finishing processes.

Wool finishing processes can be divided into two; wet and dry. The wet processes generally flow as in Fig. 1.

![Fig. 1 Wet Processes for Wool Fabrics](image)

The purpose of scouring is not only rinsing fabrics but also obtaining two following functions which are most essential in the finishing processes:

1. Increasing whiteness and pattern brightness by removing oil, dust, soil, singeing dust, etc. attached during spinning and weaving processes;
2. Rendering so-called “handle,” coming from such character of wool as softness and elasticity, by squeezing the swelled fabrics so that the porosity of yarn meshes and yarns themselves are enlarged and the fabrics get bulky.

Since the product qualities depend mainly on the scouring process, it is difficult to exchange the old scouring machine for a new one without careful consideration. The rope scouring aiming at the function (2) above mentioned requires as many times of squeeze as 100 to 200 and the operating conditions are widely varied. These reasons make it difficult to convert the conventional batchwise machines to high productive continuous ones. With a unique technology of “reciprocal motion”, RSC has solved this difficulty and enabled the processes before and after scouring to be connected continuously.

The RSC technology was licensed to L. PH. Hemmer, West Germany, in January 1977. The first line of RSC has been operating as a main force at Mie Mill, Toyobo.

2. Outline of RSC

RSC stands for “Continuous Reciprocal Scouring Machinery.”

A scouring machine called Dolly washer, in which ropes of wool fabrics are batchwisely scoured, has been used for many years. RSC is a continuous machine which can take place of Dolly washers. Its most typical feature is the reciprocal motion that fabrics go forward little by little after repeated forward and backward motion. For example, 100 m forward and 80 m backward motion results in 20 m forward proceeding. As illustrated in Fig. 2 the machinery comprises
of three scouring baths connected in one direction. Each of the baths is equipped with an independent driving part. These parts drive reciprocally in accordance to the predetermined programs of forward and backward proceeding. Three baths are connected by connecting parts which also drive the fabrics at a speed corresponding to the fabric proceeding. All the systems are under one control.

A pair of nip rollers, installed in each bath, has ten nip points. Fabrics treated go spiral by through 30 nip points in three baths. Thus, roller-nipping can be made between 100 and 270 times discretionally. Table 1 shows specification of RSC.

Generally speaking, RSC is five times in productivity as much, and half in production cost as less as Dolly washers. Table 2 supports this fact. The handle of fabrics scoured are not almost different between Dolly washers and RSC.

Fig. 2 RSC Machinery

<table>
<thead>
<tr>
<th>Table 1 Specification of RSC Machinery</th>
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<tbody>
<tr>
<td><strong>Type</strong></td>
</tr>
<tr>
<td>Working width</td>
</tr>
<tr>
<td>Material to be treated</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Standard weight:</td>
</tr>
<tr>
<td>Production capacity</td>
</tr>
<tr>
<td>Main bath</td>
</tr>
<tr>
<td>Measurement:</td>
</tr>
<tr>
<td>SUS 304, 2 mm in thickness</td>
</tr>
<tr>
<td>Main roller</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Middle bath</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Take-up roller</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Beating roller</td>
</tr>
<tr>
<td>Fabric driving speed</td>
</tr>
<tr>
<td>Motor</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Loop correction device</td>
</tr>
<tr>
<td>Control panel</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Safety device</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Floor space</td>
</tr>
<tr>
<td>Minimum lot</td>
</tr>
</tbody>
</table>
3. Target and problem of Development and Settlement

The purpose of RSC development was to increase the productivity and to improve qualities in rope scouring process. In particular it was:
(1) Continuation—Almighty continuous machine
(2) Improvement of qualities—Equal or better
(3) Lower cost—Half or less
(4) Less water—Half or less

Mere mass-production machines are not necessary for finishing wool fabrics. Wool finishing is on the basis of many kinds and small lots, and encounters frequent change of lots. These result in difficulty for continuous operation and good quality control, cost out and utility saving.

Continuation is the most important for manpower saving and cost cut to bring quality stabilization and improvement, and resources saving. But for wool finishing, lot by lot control is strictly required and is often called artful control. Also, the material to be treated is very expensive, and the qualities are often accounted more important than realizing continuation in the wool finishing field.

The conventional rope scouring is a batchwise process to be done for such a long time as two to three hours to get 100 to 200 times of squeeze. The effect of such squeeze could not be obtained by a simple continuous machine and, even if possible, other trouble would be unavoidable. This is the reason why the alternation was difficult. At the same time consideration had to be given to saving inlet and outlet water.

To solve the above-mentioned problems the RSC development was aimed at the following means:
(1) Realization of continuation by reciprocal motion —continuous production at a wide applicable range.
(2) Numerization of handle —Exact evaluation of scouring effect.
(3) Adopting Dolly mechanism —Avoidance of drastic change of scouring principle.
(4) Saving water by counter-flow —Minimizing amount of inlet and outlet water.

4. Mechanism and Control System

The function of RSC is roughly divided into five:
(1) Liquor bath part for rinsing and relaxing.
(2) Roller part for rubbing and delivering fabrics.
(3) Mangle part for controlling input and output in each bath.
(4) Loop correction device for controlling loop length.
(5) Control panel for controlling all the functions.

Figs. 3 to 5 illustrate the functions mentioned in (1), (2) and (3).

The mechanisms are automatically controlled under the following control systems:
(1) Reciprocal motion control
(2) Fabric stock control for side baths
(3) Loop length control
(4) Counter-flow control
(5) Temperature control for bath liquor
(6) Supply control of detergents

### Table 2 Comparison between RSC and Dolly

<table>
<thead>
<tr>
<th></th>
<th>RSC 3 baths A</th>
<th>Dolly 10 baths B</th>
<th>Ratio A/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>23 kW</td>
<td>19 kW</td>
<td>1.21</td>
</tr>
<tr>
<td>Steam</td>
<td>0.93 ton</td>
<td>1.71 ton</td>
<td>0.79</td>
</tr>
<tr>
<td>Water</td>
<td>15 m³</td>
<td>60 m³</td>
<td>0.25</td>
</tr>
<tr>
<td>Detergents</td>
<td>10 kg</td>
<td>13 kg</td>
<td>0.77</td>
</tr>
<tr>
<td>Labour</td>
<td>1</td>
<td>5</td>
<td>0.20</td>
</tr>
<tr>
<td>Total operation cost</td>
<td>0.54</td>
<td>1</td>
<td>0.54</td>
</tr>
<tr>
<td>Floor Space</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RSC 3 baths A</td>
<td>about 90 m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dolly 10 baths B</td>
<td>about 300 m²</td>
<td></td>
<td>0.30</td>
</tr>
</tbody>
</table>
In particular, the control systems (1), (2) and (3) are characteristic to RSC and much time has been spent for developing these systems.

5. Newly Developed Technology

5.1 Various Problems of Reciprocal Motion

In the reciprocal motion fabrics pass through a given nip point many times. The number of passing \( n \) can be calculated by:

\[
\begin{align*}
\text{(1)} \quad n &= \frac{nD\text{R}_1}{(nD\text{R}_1 - nD\text{R}_2)} + \frac{nD\text{R}_2}{(nD\text{R}_1 - nD\text{R}_2)} = \frac{\text{R}_1 + \text{R}_2}{\text{R}_1 - \text{R}_2} \\
\end{align*}
\]

where

- \( D \): Diameter of scouring roller (m).
- \( \text{R}_1 \): Number of revolution of scouring roller at forward going.
- \( \text{R}_2 \): Number of revolution of scouring roller at backward going.

If the rollers have nip points of \( C \), then the total roller nipping number \( N \) is:

\[
\begin{align*}
\text{(2)} \quad N &= \frac{(\text{R}_1 + \text{R}_2)}{(\text{R}_1 - \text{R}_2)} C.
\end{align*}
\]

The fabric delivery speed \( V \) (m/min), which means how much the fabrics go forward under the reciprocal motion, is given by:

\[
\begin{align*}
V &= \frac{\text{Proceeding length for one cycle of reciprocal motion}}{\text{Time required for one cycle}} \\
&= \frac{(R_1 - R_2)\pi D}{R_1 + R_2 + \frac{2t}{r}} - \frac{(R_1 - R_2)\pi D}{R_1 + R_2 + \frac{2t}{r}} \\
\end{align*}
\]

where

- \( t \): Stopping time for alternation between forward and reverse revolution (sec).
\( r \): Revolution speed of scouring roller (rpm).

Fig. 6 illustrates the relation between \( N \) and \( V \), which can be obtained by combining eqs. (2) and (3), for a standard RSC (30 nip points).

At first, it seems easy to alternate forward and reverse revolution while squeezing the fabrics, but there are many problems to be solved for continuous operation with repeated and quick alternation. For example:

1. Trouble caused by inertia.
2. Fabric looseness and entanglement caused by the alternation.
3. Timing to change forward and backward motion and productivity.
4. Problem concerning frequent repetition of start and stop.

The RSC Machinery was trially manufactured and modified at least several times before completed in such a mechanism as illustrated in Fig. 3. Much effort was made to solve the problem (2) above. In particular, many design changes were made as to the place of scouring rollers, take-up rollers and guide rings, and to the shape of baths in order to make the reciprocal motion stable.

The stopping time has great influence upon the reciprocal motion. Fig. 7 gives the relation between the stopping time \( t \) and the fabric delivery speed \( V \).

For example, under the program of 50 time forward and 30 time reverse revolution, the stop for 5 seconds and the delivery speed of 22.3 m/min define point B. But at point A, the time of alternation is 2.3 seconds and the delivery speed is 23.6 m/min; this means the productivity increases easily by 5 percent or more. Similarly, shifting point D \((t = 6)\) to point C \((t = 2)\) makes productivity increase of 9 percent.

Thus the alternation must be quick and, at the same time, the mechanism must be simple and reliable. This is the reason why RSC adopts such means as changing the motor driving direction instead of clutch mechanism.

Another problem of the reciprocal motion is how to choose suitable motors. Generally speaking, DC motors have an advantage of quick start-up, but AC induction motors for general purposes are more advantageous from the points of maintenance, cost, etc. RSC uses AC induction motors and the torque necessary for start-up is obtained by a special method.

The three baths are started one by one from the first bath in order that the load at start-up is not centralized to the electric source at the same time. Fig. 8 shows the phase-lag of each bath, in which \( S_1 \) is the first start-up, \( H \) an emergency stop, \( S_2 \) the restart after \( H \). At \( G \) where the first and the second bath are to be started up concurrently because the forward and the reverse program meet, the first bath starts up later to prevent the double start-up.

### 5.2 Take-up Rollers and Fabric Qualities

Scouring is usually done at the temperature of 30 to 40°C except for special cases. Rinsing is efficiently done at this range of temperature, but the wool, well swelled and softened, is easy to encounter strain, which may affect the final product. Scour crease is one of the examples. It is most important to avoid stretch by scouring.

By scouring, wool fabrics are shrunk in both length and width and increase the thickness and bulkyness, giving soft handle. In particular this effect is related most to the length shrinkage. Fig. 9 illustrates the correlation between scour shrinkage and sensory evaluation.

The RSC Machinery has unique fabric paths which are specially designed to improve the length shrinkage based on the above test results.

Fig. 10 shows relative positions between main scouring rollers and take-up rollers: A is the original type of RSC; B and C are the types developed after a lot of researches.

In type A, the fabrics from main scouring rollers are taken
Up by a pair of nip rollers, and the speed difference to avoid fabric entanglement is 0.2 to 0.5 percent. Type B has no nip rollers, and is equipped with take-up rollers, which touch the fabrics at a large angle. It has such great speed difference as 7 to 10 percent to stabilize the take-up of fabrics. In type C, the flow of scouring liquor from the squeezed fabrics is considered important. But the unstable take-up needs speed difference of 30 percent or more, and a pair of non-nipping rollers must be used for take-up when unstable.

Scour shrinkage which finally affects the properties of finished fabrics depends on the types of take-up rollers. For example, the fabric finished by type A has less thickness, and is hard to be bent and stretched in the longitudinal direction, unflexible to shearing stress and less lustered.

5.3 Side Bath and Stock Control

For continuous operation, the side baths must have stock fabrics sufficient for the forward and the backward going of fabrics, including some spare amount for continuation of such going. The control of this is the stock control. In addition to the fabric stock, the side baths have a function to restrain from a change of loop length. The load to lift up the fabrics depends on how much liquor the fabrics contain. The difference in the load makes the loop length different after a lapse of time. To minimize the change of loop length, the side baths are installed in the main bath.

Fig. 11 shows the change of loop length depending on the types of side baths. In A, where the fabrics come from and go to a non-liquor side bath, the first loop gets longer at a rate of 7 to 13 m/hr. In B, where the fabrics move to and from a side bath with sufficient amount of dipping liquor, the change of loop length can be controlled to such short extent as 2 to 3 m/hr.

When the stock in the side bath is detected by the emptiness there, the reciprocal motion to send the stock at a speed of 100 m/min stops, only a certain supply part continuing to feed.

The inertia at stop is absorbed by dropping rollers (3) in Fig. 4 and (8) and (6) in Fig. 5, and also by momentary release of the nip points at the mangle. This mechanism avoids strong tension on fabrics.

This stock control is made in the way that the delivery speed is increased little by little along the machine direction so that emptiness is always detected. When detected the side bath and the parts thereafter stop and wait until the necessary supply is completed.

The following formula expresses the relation among the speed difference, the supply time and the interval at which the supply control takes place.

Fig. 9 Correlation between Scour Shrinkage and Sensory Evaluation

![Diagram](a)

![Diagram](b)

![Diagram](c)

Fig. 10 Fabric Take-up Mechanism

![Diagram](Fig. 11 Change of Loop Length)

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T = \frac{t}{60} \quad \frac{\alpha}{100} \quad \text{Equation (4)}

T: Interval of supply cycle.

\( t \): Supply time.

\( \alpha \): Ratio of difference between speeds at inlet and outlet of the side bath.

Equation (4) is plotted in Fig. 12 for the convenience of selecting suitable conditions.

\[ R_2' = \frac{60R_1(\pi Dr - V_0) - 2tV_0r}{60(V_0 + \pi Dr)} \quad \text{Equation (5)} \]

\[ \Delta R_1 = R_1 - R_1' \quad \text{Equation (6)} \]

where

\( R_2' \): value of the backward program at stop when the stock in the outlet side bath gets empty.

\( R_1 \): Predetermined value of forward program.

\( R_2 \): Predetermined value of backward program.

provided \( R_2 > R_2' \)

\( V_0 \): Delivery speed of the middle mangle.

\( \Delta R_2 \) is usually less than 1 unless special conditions are set up. The speed difference \( \alpha \) is preferable to be 2 to 3 percent.

Stages A through F in Fig. 8 show the relation between the reciprocal motion and the supply control which is conducted in the inlet side bath of the first main bath and at five other points thereafter. At stages B, D and F in Fig. 8, namely when the stock shortage is detected in the side bath during the backward movement, the fabric for stock can not be supplied merely by stopping the drive at the back part. In this case the programs for the backward are cut and the forward going start immediately to feed fabrics into the side bath. The blackened portions at stages B, D and F indicate the cut of program. The influence of cutting the program is very small, usually less than the fabric delivery of about 1.6 m which is carried by one revolution of the scouring rollers.

The following formulae give how much the backward program has gone till it is cut.

\[ \frac{1}{60} \frac{\alpha}{100} \]

Fig. 12 Conditions for Stock at Side Bath

Stages A through F in Fig. 8 show the relation between the reciprocal motion and the supply control which is conducted in the inlet side bath of the first main bath and at five other points thereafter. At stages B, D and F in Fig. 8, namely when the stock shortage is detected in the side bath during the backward movement, the fabric for stock can not be supplied merely by stopping the drive at the back part. In this case the programs for the backward are cut and the forward going start immediately to feed fabrics into the side bath. The blackened portions at stages B, D and F indicate the cut of program. The influence of cutting the program is very small, usually less than the fabric delivery of about 1.6 m which is carried by one revolution of the scouring rollers.

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\( R_1 \): Predetermined value of forward program.

\( R_2 \): Predetermined value of backward program.

provided \( R_2 > R_2' \)

\( V_0 \): Delivery speed of the middle mangle.

\( \Delta R_2 \) is usually less than 1 unless special conditions are set up. The speed difference \( \alpha \) is preferable to be 2 to 3 percent.

5.4 Change and Correction of Loop Length

A small slip difference of fabrics in a spiral form on the scouring rollers results in a change of loop length, in a long time. The preferable loop length is between 20 and 50 meters. The loop length is controlled to avoid the fabric damage with such a device as shown in Fig. 13.

A loop, which is longer than the allowable range, is judged as a “too long loop”, and a shorter as a “too short loop”, and the sequence control is done in accordance with this judgement automatically while normal operation.

The loop correction can be done by the two following methods:

(1) Correction by moving the portion to be corrected.

Fig. 13 (a) Loop Correction Device
(The correction is not being done)

Fig. 13 (b) Loop Correction Device
(The correction is being done)
Correction by stopping the portion to be corrected and moving the other portions all at once.

Fig. 14 is a flowchart of correction by the device illustrated in Fig. 13. Fig. 15 is its developed diagram.

The metallic object X in Figs. 14 and 15 must be selected from such points as are easily detected by proximity switches, photo-eyes, etc. Further, those objects must be durable to nipping at the rollers and capable of bending, and have no possibility of rust.

In Fig. 15, A is the loop of which correction is under way, and B is the loop to be corrected next. When A' loop has been completed its correction, B' loop has the influence resulting from the correction of A' loop.

By this method two neighbouring loops are sometimes corrected at the same time. For example, if B' loop is within the allowable range, the loop correction device does not work at B' loop, and moves to the next loop for measurement, saving in time.

The first loop, as explained in Fig. 11, has the tendency to become a little longer, but other loops do not have such a clear tendency. When a loop gets longer, the neighbouring loop or loops often get shorter.

5.5 Counter-flow and Bath Liquor Control

Another advantage of continuous scouring is to cut down the inlet and outlet water by means of counter-flow. As the water pollution control regulation gets severer, the cut of rinsing water becomes a great concern.

The three baths of RSC are completely controlled by counter-flow. The inlet water, to be poured into the third bath, ranges between 6 and 15 m³/hr, depending on the turbidity at baths.

The water in a main bath is carried by the running fabrics to the middle bath, and then to the next main bath. The flow amount is controlled by the change of water level in the main bath.

According to the theory, the washing parameter $K$ is expressed by

$$K = \frac{C_i - C_{we}}{C_i - C_{w_e}} = BR$$

where

- $K$: Washing parameter
- $C_i$: Concentration of impurity included in the fabric before entering the wash water.
- $C_{we}$: Concentration of impurity in the wash water.
- $C_e$: Concentration of impurity included in the fabric after wash.
- $B$: Diffusion washing parameter
- $R$: Squeeze factor.

When $n$ baths, each having value $K$, are connected, the total rinsing parameter is said to be $K^n$ approximately.

Therefore, better rinsing effect can be obtained by decreasing $K$ value of each bath or increasing the squeeze and dispersion effect, and by connecting as many baths as possible.
Thus, each bath of RSC is divided into three parts, and designed so as to give a gradient of concentration to the rinsing water in those three parts.

In order to keep the rinsing water for continuous scouring in a steady state, it is necessary to put unsoured fabrics, detergents, and diluting water regularly at a certain ratio. This can be pretty easily controlled, if the relevant conditions are searched and set.

6. Plant Design with RSC and Future Technology of Wool Finishing

The standard RSC Machinery for continuous scouring is composed of three consecutive baths with 30 nip points, but it is possible to design a machine with more baths or less nip points.

Water can be saved by increasing the number of baths to four, and can be reduced to as less as 12 to 15 l/kg wool.

There is a possibility to use a micro-computer for changing lots and operation conditions.

To decrease nip points per bath may be suitable for production on a small scale. However, from the viewpoint of investment, the actual and convenient scale is three to four baths and total nip points of 20 to 32.

Fig. 16 shows the relation among the total number of nip points $C$, fabric delivery speed $V$ and total roller nipping number $N$. $C$ can be calculated by the following formula in which letters are the same that defined in eq. (3):

$$C = \frac{NV}{R + \frac{fr}{60}}$$

The continuous rope scouring realized by RSC has paved the way to a continuous connection of the processes for wool wet finishing. With cumulation of the related know-how, a fully automatic plant will be completed. Fig. 17 illustrates one of the plans proposed for such a plant which can be realized at any factory operating on the basis of pretty large lots.

7. Summary

The RSC Machinery, developed with about ten-year efforts including many modifications and actual long operation, is said to be a very unique machine. It was developed not by a machine manufacturer, but by a user without hurry. During the development a lot of technical obstacles and stagnation were encountered.

As the above-mentioned is only a brief explanation, it might be difficult to evaluate the machinery precisely. As the summary, the features of RSC are given as follows:

1. RSC is a continuous scouring machine applicable to such nipping as much as 100 to 270 times on discretion conditions.

2. The standard RSC Machinery comprises of three consecutive baths which have individual mechanism of reciprocal motion. Therefore the lot change can be done bath by bath. This is applicable to the production on the basis of many kinds and small lot.

3. The scouring principle of RSC is not different from that of the conventional machines. Therefore the same handle is obtained and, in addition, the scouring crease is dispersed and unnoticed.

4. The mechanism of RSC is very simple, and the maintenance is very easy.

5. The productivity of RSC is very high thanks to the various automatic control. Its operation cost is about half as low as that of the conventional batchwise ma-
chines.

The patents and patent applications for the RSC technology amount to eleven (including one utility model) in domestic and five foreign countries. There is one overseas license.

A few of other continuous rope scouring machines, developed in domestic and overseas, are known at present. None of them, however, has such unique features and advantages as the RSC Machinery.