Pipe Scouring — A New Method for Scouring Greasy Wool

By Yoshihira Matsuzaki and Jun-ichi Sekiguchi, Members, TMSJ

Research Institute for Polymers and Textiles, Yokohama

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Abstract

A new wool scouring system which can take place of the conventional type has been developed. Its main characteristics are (1) the use of a pipe as a scouring bowl in which wool fleece is scoured by a stream of washing liquid, and (2) the use of air flow for the agitation of wool and liquid in the pipe.

This article describes the mechanism and the scouring principle of this system and some experimental results. The main conclusion from experiments using a medium-scale test equipment is as follows;

- (1) Although some minor problems are left unsolved, this new system can be put into practical use as an improved wool scouring system.
- (2) The composition of the scouring solution and the treatment time with this method are the same as those with the ordinary method. The most appropriate air flow rate per unit time is about one fifth of the liquid flow. It should be large in the first bowl and then be gradually decreased as the wool is scoured.
- (3) The inclination of the pipe should be as large as possible. In the test reported here no problems occurred with tilt angles up to $8^{\circ}30'$, which was the highest used.
- (4) The equipment is suitable for many uses. For example, continuous materials such as sliver or fabric pass it through smoothly without being stretched, twisted or jammed. It is therefore possible to use it for continuous wet treatments.

KEY WORDS: SCOURING, GREASY WOOL, SCOURING BOWLS, WOOL FLEECES, SLIVERS, HOPPER FEED, OPENERS, FEED LATTICES, STROBOSCOPES POLY (VINYL CHLORIDE), SCOURED WOOL, FELTING, MERINO WOOL, WORSTED SYSTEM SPINNING, TOW, NOILS

1. Introduction

The way of wool scouring used today has been left unchanged for almost one hundred years. Although it is very suitable for scouring delicate fibers such as raw wool, it is rather old fashioned in this technical innovation age. Therefore a number of investigators have tried to develop new scouring methods and equipments for raw wool. Recent examples are aqueous jet scouring^[1], suction drum scouring^[2] and the WIRA improved scouring set^[3]. The authors were interested in the improvement of scouring systems, and in 1968 constructed a medium-scale machine based on a new idea. Scouring tests using this equipment have been continued until now. Although there are left some problems to be solved in the new scouring system, there seems to be no doubt that it is practicable, and so a description of this system with some experimental results will be described below.

2. Problems of Conventional Equipment

There are two great problems with conventional equipment. The first is that the equipment is too large. The length of a scouring set including hopper feeder, opener and dryer is up to 60 m, and the area of a scouring room with working space may exceed 300 m². This is therefore one of the largest textile machines.

The second is the large heat loss due to the open type equipment which amounts to a colossal sum throughout a year. Using the conditions given in Tables 1, 2 and 3 for a five-bowl conventional scouring set, the heat balance is calculated and shown diagrammatically in Fig. 1.

It is clear from the figure that the heat loss in conventional equipment is very high, and this does not include the loss involved in making new washing liquid. Altogether, total loss about 1,450,000 kcal per hour is lost, of which 670,000 kcal, or about 45%, is due to the open nature of the equipment.

Fig. 1 Heat balance for conventional wool scouring equipment

3. Description of the Machine

A single scouring bowl is shown diagrammatically in Fig. 2, in which opened raw wool is dropped into the funnel shaped entrance (2) from the feed lattice (1). Washing liquid is sent from the liquid tank (3) to the same funnel-shaped entrance by a pump (4), and is mixed with raw wool. Hereinafter, the mixture of wool and washing liquid is referred to simply as "mixture".

The mixture flows down the vertical pipe, and reaches the scouring pipe (6) after passing the bottom compartment (5). It is necessary for the scouring pipe to be sloped upwards, for reasons which will be explained later. The pipe is set up in a spiral form in order to reduce the floor space required. (For treatment of continuous materials, the pipe would preferably be straight.) Air from an air compressor (7) is sent at a rate controlled by the valve (8), and injected from a nozzle (9) which is set under the entrance part of the scouring pipe. In this way, the mixture and the air ascend in the scouring pipe, and the mixture alone flows out from the outlet (10) of the pipe, while the air goes out from the exhaust pipe (11) which is set at the top of the scouring pipe. The mixture, after flowing out, passes through squeezing rolls (12) in the ordinary way, and the wool is transferred to the next treating process. Dirty liquid is sent to the settling tank (13) in order to separate mud. Some mud also passes through the sieve plate in the bottom of the compartment (5).

This system is called "pipe scouring", because the main part of the equipment is made up of pipes as abovementioned.

4. Scouring Principle of New System

In this system, the wool is steeped and scoured in the washing liquid, which also serves to convey the wool through the apparatus.

As shown in Fig. 2, the flow of mixture is caused by the level difference between the entrance and the exit of the pipe. Although the air from the compressor is supplied

Fig 2 Schematic diagram of the trial model

Fig. 3 Formation and translation of air bubbles

continuously to the nozzle, it forms itself into a large number of separate bubbles at the nozzle outlet. If the pipe is horizontal, the air forms a layer along the top side of the pipe as shown in Fig. 3-1. But if the pipe is slightly inclined, the bubbles travel as shown in Fig. 3-2. Of course, as some adjacent bubbles unite together during travelling, the number of bubbles generated at the nozzle is different from that at the outlet. This will be referred to again later.

In a test with a liquid velocity of 3.8 m/min and a pipe inclination of 5°, bubbles moved at several times faster than the liquid velocity. They therefore agitate the liquid and impart a rocking action to the greasy wool. Fig. 4 shows a bubble which is pushing its way to the front of a wool lump. The form and the speed of the bubble is affected by the

Fig. 4 Wool lump and a bubble in the inclined pipe

injection rate of air, the inclination of the pipe, the frictional resistance of the mixture against the bubble movement, and many other factors.

Agitation on the liquid was investigated under stroboscopic illumination by taking photographs of fishing floats positioned at different heights in a straight pipe. Fig. 5 shows that the floats at all levels are rocked by movement of the surrounding liquid, even though they are not touched directly with bubbles. This behaviour would of course be modified by the presence of wool in the pipe.

Figs. 6 & 7 show the effects of air flow rate and pipe inclination on the number and the mean volume of the bubbles. In these experiments, the flow rate of liquid (ordinary water) was 6 l/min and the inclination of the pipe was 1° ,

Fig. 6 Relation between air flow and number of bubbles passed at three kinds of pipe inclination

Fig. 5 The movement of a bubble and fishing floats photographed by stroboscope

3° or 5° . Decreasing the inclination of the pipe or increasing the injection rate of the air causes a reduction in the number of bubbles passing a given point.

Low pipe inclination favours long bubbles, with correspondingly small gaps between them. Such bubbles are easy to unite with each other in the pipe. Also, the bubble speed is low at low inclination because of reduced buoyancy. For best scouring, wool fleece should receive many feeble actions. Accordingly, it is desirable in wool scouring to reduce the flow rate of air and to increase the inclination of pipe so as to produce many small, fast-moving bubbles. However, if the system is used to treat other materials, different conditions would be selected.

5. Experimental Results and Discussion

In practice, washing liquid is always continuously removed, but this was not possible with our equipment, in

Fig. 7 Relation between air flow and mean volume of bubbles at three kinds of pipe inclination

which greasy wool from 3 kg to 5 kg was scoured at once. After one experiment was completed, the dirty liquid was discharged and a new washing liquid of different composition was poured in. The prototype system shown in Fig. 8 was designed for a throughput of 100kg raw wool per hour, viz. about one tenth of the throughput of conventional types. The specification of its main parts and experimental conditions are as follows:

Inside diameter of the scouring pipe: 12.5 cm

Length of the scouring pipe: average 14 m

Inclination of the scouring pipe*: average $8\frac{1}{2}^\circ$

Flow rate of liquid per hour: 6 m^3

Quantity of injected air per hour: 0.5, 1, 2 m^3

Residence time of wool in the equipment**: from 75 sec to 100 sec

* As the pipe is made of p. v. c., it is deformed by the heat and the weight of liquid passing through it. So the inclination shown is an average value.

** Residence time depends upon the injection rate of the air and the degree of opening of the wool.

For the first test, the washing detergents used were the same as those used at a certain mill in Japan. But, because the grease content of the wool decreased very quickly compared with the usual mill scouring, it was decided to use weaker detergent solutions. The temperature and the concentration of detergents in each stage are shown in Table 4. Greasy wool is usually scoured in five stages, but here only four stages were used because of the comparatively rapid scouring mentioned above.

The residual grease in the wool after each stage of scouring is shown in Fig. 9 for air injection rates of 2, 1 and 0.5 m^3 per hour. A logarithmic scale is used for residual grease in order to magnify the low readings. For comparison with these results, is shown an example of conventional

Fig. 8 The experimental equipment for wool scouring

Fig. 9 Residual grease of wool shown by semi-logarithm at three kinds of air flow

scouring at a mill using the same lot of wool. The figure shows that the scouring rate varies with the air flow rate. The quality of the scoured wool was assessed visually, and it was found that the wool was a little bit felted when the air flow rate was 2 m^3 per hour, and that it was a little dirtier at 0.5 m^3 than at the other air rates. The former shows that the scouring action was too intense for wool, and the latter shows that the removal of dirt was insufficient under the mildest agitating action. Therefore, in order to scour greasy wool sufficiently without felting, it was necessary to use low air-flow rate and to increase steeping time and numbers of scouring stages or to change the concentration of detergent.

In another series of experiments, the state of entanglement was assessed after each stage of scouring at an air-flow rate of 2 m^3 per hour. No felting could be detected after the first and the second stages, and very slight felting was present after the third and the fourth stages. It appeared from these tests that wool is comparatively hard to felt in the early stages of scouring. It follows that in an ideal scouring procedure, the agitating action should be comparatively intense at first, and gentler step by step as scouring proceeds.

This idea was confirmed in two experiments where the air-flow rates in the first three stages were either 2, 1 and 0.5 m^3 per hour, (A-test) or 0.5, 1, and 2 m^3 per hour (B-

Table 1 Conditions measured or assumed for heat loss calculation

Room temperature	20°C	Grease content at entrance	15%
Room humidity	65% RH	Residual grease	0.7%
Temperature of water supplied	15°C	Feed rate of greasy wool	1 t/hr
Wool temperature at entrance	20°C	Scouring yield	65%
Wool temperature at exit	42°C	Specific heat of wool	0.4
Regain of wool at entrance	13%	Specific heat of wool grease	0.6
Regain of wool at exit	70%	Radiation coefficient of wall surface of bowl	0.9

Table 2 Conditions of Scouring Bowls

Bowl Number	Capacity of Bowl (kl)	Area of Bowl wall (m ²)	Area of Liquid exposed to air (m ²)	Temperature (°C)	
				Liquid	Wall
1	5.50	25.67	11.55	49	46
2	5.50	25.67	11.55	47	44
3	4.13	19.96	8.08	46	43
4	4.13	19.96	8.08	46	43
5	4.13	19.96	8.08	45	42
(Total)	23.39	111.22	46.54	—	—

Table 3 Inflow and Outflow Conditions of Liquid at Scouring Bowls⁴

Bowl Number	Inflow	Quantity l/hr	Outflow	Quantity l/hr
1	From No. 5 bowl	14,200	By drainage	13,400
	By heat exchange	200	By removal of dirt	600
			To No. 2 bowl	400
(Total)		14,400		14,400
2	From No. 1 bowl	400	By removal of dirt	600
	From No. 3 bowl	1,900	To the settling tank	6,800
	From the sludge separator	4,700	To No. 3 bowl	300
	By new washing liquid	300		
(Total)		7,300		7,300
3	From No. 2 bowl	300	To No. 2 bowl	1,900
	From No. 4 bowl	1,700	To No. 4 bowl	300
	By new washing liquid	200		
(Total)		2,200		2,200
4	From No. 3 bowl	300	To No. 3 bowl	1,700
	From No. 5 bowl	1,600	To No. 5 bowl	300
	By new washing liquid	100		
(Total)		2,000		2,000
5	From No. 4 bowl	300	By drainage	5,700
	By supply of original water	19,400	To No. 1 bowl	14,200
			To the dryer	400
(Total)		21,800		21,800

Fig. 10 Residual grease of wool at two kinds of scouring conditions

test) respectively. In both experiments, the fourth (rinse) stage had an air-flow rate of 0.5 m^3 per hour. The results are shown in Fig. 10 where Curve A represents A-test, Curve B B-test. There is little difference between them in the final residual grease content achieved, but the scoured wool in B-test was more entangled than that in A-test. Conventional wool scouring equipment has usually shorter baths in the third, the fourth and the fifth scouring stages than those in the first and the second, in order to prevent wool entanglement. However, the mechanical agitating action of conventional equipment cannot be changed even if the kind of wool or the state of scouring is different. In the new system described above, the agitating action can be changed very easily by adjusting the volume of injected air.

6. Advantages of the New Scouring System

The system is expected to have the following practical advantages:

- (a) The capital cost of the equipment will be less, and the floor space required will be smaller. The floor space required is estimated to be about 6 m^2 , which is about one half of that needed for the conventional equipment having the same treatment capacity.
- (b) As the heat loss from the new system is very small, the manufacturing cost of wool will be reduced.
- (c) The degree of agitation may be easily varied by adjusting the air valve in accordance with the character and the

state of wool. This contributes to the wool quality control and may permit to reduce the scouring process from five to four stages.

(d) The equipment is particularly suitable for such treatment as generate offensive or harmful gas, since the equipment is totally enclosed and the gas generated can be piped away for disposal.

(e) As the total quantity of liquid used in the system is less than that in the conventional equipment, it is easy to control both the concentration of chemicals and the temperature of the liquid.

Some aspects of the process that should be studied further before it is used commercially are as follows:

(a) The liquid flow from the exit of the scouring pipe is very much compared with the conventional system (about fifteen to twenty times), and this may cause difficulties. For instance, wool fleece flowing out from the exit may be entangled in the turbulent region between this point and the squeezing apparatus. Also, wool tends to flow down with liquid and be lost. However, wool and liquid may be separated quite easily by such an arrangement as shown in Fig. 11.

(b) When the equipment is used as the first or the second scouring stage for greasy wool, dirt must be separated from liquid so that the liquid may be reused. The bottom compartment shown in Fig. 2 was set up as a dirt store, but it is known from the experiment that almost all the dirt is carried along with the liquid and does not settle during scouring. Methods for treating dirt are currently being investigated.

(c) As mentioned above, the new method has such advantages as keeping the liquid volume in the equipment small. But this necessitates careful control of detergent addition in order to maintain the scouring efficiency of the liquid.

Fig. 11 An example to separate wool from liquid

- 1 Exit of scouring pipe
- 2 Guide plate
- 3 Net conveyor
- 4 Spouting nozzle of liquid to detach wool from net conveyor
- 5 Squeezing roller
- 6 Separated liquid

Table 4 Composition and Temperature of Scouring Solutions

Scouring Stage	Concentration of Soap (%)	Concentration of Soda Ash (%)	Temperature of Liquid (°C)
1	0.05	0.07	49
2	0.10	0.05	47
3	0.07	—	47
4	—	—	46

7. Conclusion

(a) "Pipe scouring" is a practical method of wool scouring, and offers advantages over conventional methods. There does not appear any practical difficulties that would prevent its commercial use.

(b) The most appropriate air-flow rate varies according to the detergent concentration in the liquid, the steeping time, and the ratio of liquid to wool. In the case of merino wool for worsted spinning suitable air-flow rate is about one fifth of the scouring liquid flow. It should be high in the first scouring stage, and gradually decreased as the wool is scoured.

(c) The inclination of the scouring pipe should be as large as possible. No problems occurred up to a tilt angle of about 10°, which was the limit of our experiment. When this system is used for other purposes, e. g. the continuous

rinsing of dyed cloth, which requires more intense action than wool scouring, the inclination of the pipe should be as nearly horizontal as possible.

(d) To investigate the applicability of this system to the field other than wool scouring, experiments were carried out using noil and endless textile materials such as man-made fibre tow or hosiery cloth. These passed very smoothly through the equipment without being stretched, twisted or jammed. So it seems that the equipment would find general use for continuous wet treatment.

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