# Determining conducive processing conditions for wool fibres

ARUP RANJAN MUKHOPADHYAY
*SQC & OR Unit, Indian Statistical Institute, India*

ABSTRACT *Wool fibres are very sensitive to the atmospheric processing conditions on the shop-floor, while the atmospheric condition within the shop-floor is again dependent on the ambient condition outside the shop-floor, which varies from season to season. This study helps to identify the best atmospheric conditions along with the expected fibre length (called the expected Hauteur) and the desired coefficient of variation of the expected fibre length (called the expected Hauteur CV%), corresponding to which the actual fibre length (known as the actual Hauteur) will be maximized, resulting in a substantial increase in yield. Of course, to achieve this, one will have to maintain the atmospheric conditions within the shop-floor as suggested in this study by resorting to appropriate measures in the form of steam injection, particularly during the winter season when both temperature and relative humidity fall. The expected tangible gain from the study is estimated to be around rupees 14.328 lakhs per annum, which can be considered as a conservative estimate in the opinion of the management of the concerned Indian textile industry.*

## Introduction

Wool fibre generates static electrical charges during processing because of its friction with the metallic parts of the machinery. Unless this charge is neutralized by a media which is conductor of electricity, the fibres tend to scatter in all directions, resulting in lapping and fibre breakage. This, in turn, reduces productivity, expressed in terms of *Top Yield* in the wool combing department.

The best conducting material for this purpose is water present in the wool. If the relative humidity percentage (RH%) of the processing area is too low, the moisture content in wool evaporates fast, causing accumulation of static charge, which subsequently causes fibre breakage, a reduction in Hauteur length and a decrease of top yield due to the generation of more noils or waste.

## Objective

To arrive at the optimum operating conditions, including departmental humidity and temperature, corresponding to which the Actual Hauteur Length, i.e. the Actual Fibre Length and Yield—specifically known as Top Yield—will be maximized and, in turn, the difference

between actual Hauteur length and expected Hauteur length will also be maximized. The expected Hauteur length is calculated by the overseas supplier for a consignment.

## Data

Keeping in view the above objective, data are compiled for about one year (January 2000 to January 2001) from the records of the Wool Combing and Engineering department on the following characteristics, by maintaining one-to-one correspondence:

- Lot number
- Date
- Relative Humidity % (RH%)—Minimum
- Relative Humidity % (RH%)—Maximum
- Humidity in terms of Grain (grams per cubic feet)—Minimum
- Humidity in terms of Grain (grams per cubic feet)—Maximum
- Dry bulb temperature in °F—Minimum
- Dry bulb temperature in °F—Maximum
- Expected Hauteur in mm
- Actual Hauteur in mm
- Expected Hauteur CV%
- Actual Hauteur CV%

## Analysis

Stepwise multiple regression has been used for analysing the data. A SPSS package (PC version) is used for this purpose. The following relationship has been obtained:

$$\text{Actual Hauteur} = 47.713 + 0.734 \times \text{Maximum Grain} + 0.663 \times \text{Expected Hauteur} - 0.536 \times \text{Expected Hauteur CV\%}$$

With $R = 0.859$
$R^2 = 0.738$
Adjusted $R^2 = 0.717$
Standard error of the estimate = 2.11048
Number of data sets = 41

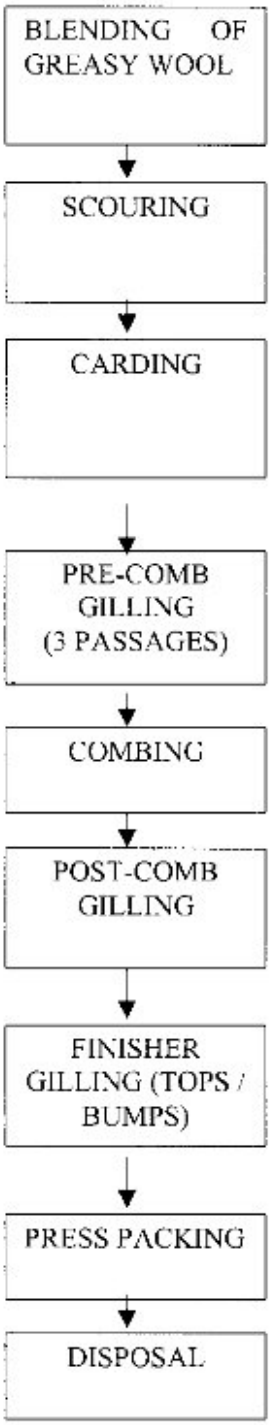
The corresponding model adequacy checks are provided in Appendix 1.

It can be concluded that about 72% of the variation in Actual Hauteur can be explained through the above relationship. The descriptive statistics for the characteristics in the above equation are given in Table 1.

**Table 1.** *Descriptive statistics*

| Characteristics | *N* | Minimum value | Maximum value | Mean | Standard deviation |
|---|---|---|---|---|---|
| Maximum Grain | 41 | 7.0 | 12.8 | 10.40000 | 1.40943 |
| Expected Hauteur | 41 | 64.7 | 81.9 | 70.13902 | 3.20717 |
| Expected Hauteur CV% | 41 | 33.6 | 49.7 | 42.46829 | 4.12943 |
| Actual Hauteur | 41 | 72.7 | 86.8 | 79.11951 | 3.96889 |

**Process flow chart of wool combing department**




- Blending of different sub-lots to obtain a homogeneous product.
- Removal of natural grease, suint, dust and dirt by washing with synthetic detergent in an aqueous bath.
- Separation of individual fibres, formation of silver and removal of residual dust and vegetable matter (VM) in the form of SHODDY and BURR.
- Parallelization of fibres by drafting through an intersecting needle field, and the evenness of sliver through doubling.
- Removal of short fibres, residual VM and neps.
- Further parallelization and evenness of sliver by drafting and doubling.
- Formation of tops/bumps after final passage of gilling.
- Packing of tops/bumps by hydraulic press in bale form to facilitate storage and transportation.
- (a) Finished goods go down for in-house use.
  (b) Loading in trucks or containers for external customers.

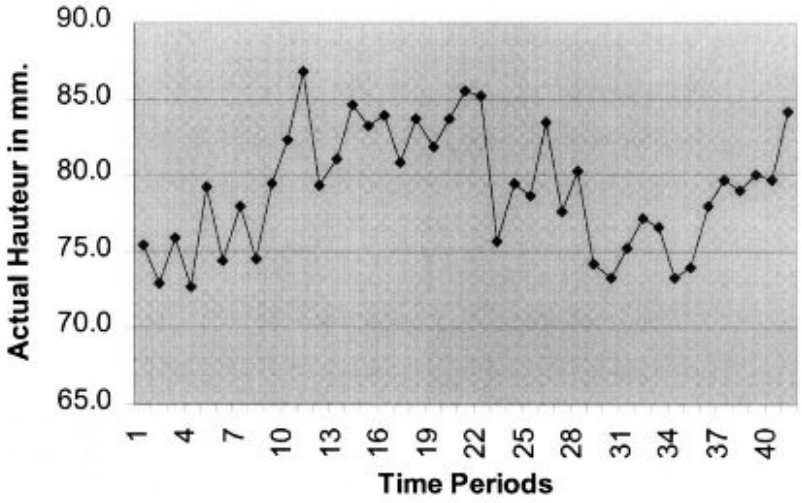



**Figure 1.** *Variation of actual hauteur over different time periods in a year.*

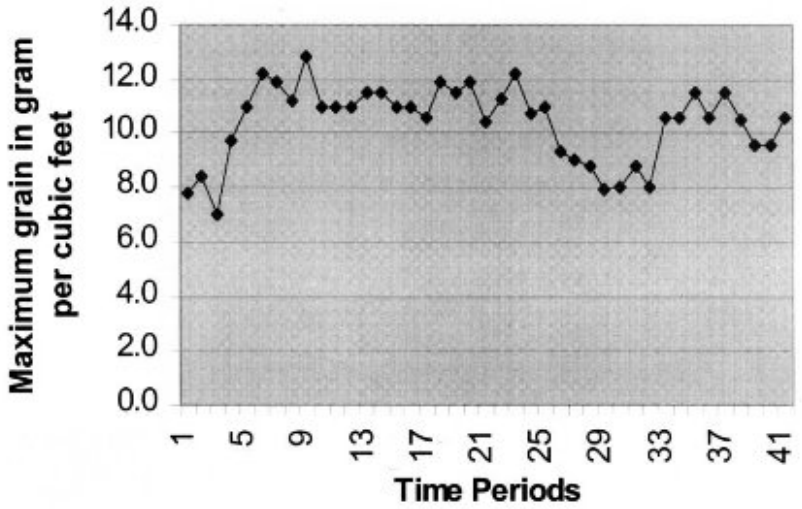



**Figure 2.** *Variation of maximum grain over different time periods in a year.*

Figures 1 and 2 demonstrate how 'Actual Hauteur' and 'Maximum Grain' vary over different periods in a year. The effect of seasonality is depicted with the help of these figures. Note that the above relationship is valid for the above-mentioned ranges of the independent variables—maximum grain, expected hauteur and expected hauteur CV%.

Since the objective is to maximize Actual Hauteur, the following formulation can be made subsequent to carrying out regression analysis:

$$\text{Maximize Actual Hauteur} = 47.713 + 0.734 \times \text{Maximum Grain} + 0.663 \times \text{Expected Hauteur} - 0.536 \times \text{Expected Hauteur CV\%}$$

Subject to

$$7.0 \leqslant \text{Maximum Grain} \leqslant 12.8$$
$$64.7 \leqslant \text{Expected Hauteur} \leqslant 81.9$$
$$33.6 \leqslant \text{Expected Hauteur CV\%} \leqslant 49.7$$

**Table 2.** *Recommended levels of characteristics*

| Characteristic | Recommended level |
|---|---|
| Maximum Grain | 12.8 grams per cubic feet |
| Expected Hauteur | 81.9 mm |
| Expected Hauteur CV | 33.6% |

**Table 3.** *Relation between atmospheric temperature and grain*

| Dry bulb temperature (°F) | Wet bulb temperature (°F) | Grain (grams per cubic feet) | Relative humidity % |
|---|---|---|---|
| 88 | 86 | 12.8 | 92 |
| 89 | 86 | 12.8 | 88 |
| 91 | 87 | 12.9 | 84 |
| 92 | 87 | 12.9 | 81 |
| 93 | 87 | 12.6 | 78 |
| 94 | 87 | 12.5 | 75 |
| 95 | 88 | 12.8 | 75 |
| 96 | 88 | 12.8 | 72 |

## Conclusion

In order to maximize the Actual Hauteur, the levels shown in Table 2 of the characteristics are obtained.

The corresponding Actual Hauteur will be $93.3983 \pm 4.1365$ with 95% confidence level. Hence, the expected difference between Actual Hauteur and Expected Hauteur is $93.3983 - 81.9000 = 11.4983$ mm. The existing difference between Actual Hauteur and Expected Hauteur is about 8.99805 mm (cf. Table 1).

## How to achieve a grain of 12.8 gms/cubic ft

Since it is the general practice to measure and control the Grain or Relative Humidity % within the shop-floor with a Dry Bulb temperature combined with the difference between Dry Bulb and Wet Bulb temperature, Table 3 is derived from the hygrometric nomograms.

## Recommendation

For smooth working of the department, the following levels of dry bulb temperature, wet bulb temperature and relative humidity are to be maintained to obtain a Grain value of 12.8 grams per cubic feet.

Dry Bulb Temperature: 95°F to 96°F
Wet Bulb Temperature: 88°F
Relative Humidity: 72% to 75%

Since the problem of a low top yield is at its greatest during the winter season, owing to a significant fall in both temperature and relative humidity, steam injection is suggested as a remedial measure to achieve the above levels.

An overseas (Australian) supplier is to be communicated with to provide raw wool with an expected Hauteur length to the tune of 81.9 mm in a consistent manner so that expected Hauteur CV% is obtained in the vicinity of 33.6% or less. The past data in Table 1 demonstrate that these values are achievable.

The first two combinations of Table 3 are not suggested due to very high relative humidity (of the order of 88% to 92%) which is again unfavourable for processing wool fibres.

## Financial impact

The expected financial gain from this study is estimated based on the seasonal difference, i.e. the difference between winter and other non-winter seasons, by the average difference between actual and expected top yield (see Tables 4 and 5).

Therefore, the difference between two seasons in average difference in actual and expected top yield % = 2.253 − 1.656 = 0.597 = 0.6 (approximately).

Average monthly top production = 330 000 kg. So, 0.6% of 330 000 kg = 1980 kg. The difference in selling price between Wool Top (i.e. good production) and Noil (i.e. waste) is about rupees 250 per kg. Hence, financial gain due to an increase in yield = 1980 × 250 = rupees 4.95 lakhs per month. Considering that there are three months (at times it extends to three and a half months) in the winter season in this region, the conservative estimate of financial gain per annum due to an increase in yield is 3 × rupees 4.95 lakhs = rupees 14.85 lakhs.

To maintain the relative humidity or grain at the prescribed level, steam injection is necessary in the wool combing department during the winter season, which spans about three months. The extent of steam consumption per day will be around 1000 kg for this purpose. The cost of steam generation is about rupees 0.58 per kg. Therefore, the total expenditure

**Table 4.** *Average difference between actual and expected top yield in winter season*

| Months | Actual top yield % | Expected top yield % | Difference in actual and expected top yield % | Average difference in actual and expected top yield % |
|---|---|---|---|---|
| Nov 00 | 95.32 | 93.68 | 1.64 | |
| Dec 00 | 95.61 | 93.95 | 1.66 | 1.656 |
| Jan 01 | 95.25 | 93.58 | 1.67 | |

**Table 5.** *Average difference between actual and expected top yield in non-winter season*

| Months | Actual top yield % | Expected top yield % | Difference in actual and expected top yield % | Average difference in actual and expected top yield % |
|---|---|---|---|---|
| May 00 | 95.24 | 93.42 | 1.82 | |
| June 00 | 96.11 | 93.48 | 2.63 | 2.253 |
| July 00 | 95.77 | 93.46 | 2.31 | |

to be incurred per year for steam injection is rupees $1000 \times 0.58 \times 30 \times 3 = 52\,200$ which is rupees 0.522 lakhs.

Hence, the net expected tangible gain from the study = rupees $(14.85 - 0.522)$ lakhs = rupees 14.328 lakhs (approximately).

## References


BOOTH, J.E. (1983) *Principles of Textile Testing* (London, Butterworths).
DRAPER, N.R. & SMITH, H. (1981) *Applied Regression Analysis* (New York, John Wiley & Sons).
HEARLE, J.W.S. & PETERS, R.H. (1964) *Moisture in Textiles* (New York, Textile Book Publishers).
MEREDITH, R. (1959) *The Mechanical Properties of Textile Fibres* (Amsterdam, Linn).
MONTGOMERY, D.C. (1991) *Design and Analysis of Experiments* (Singapore, John Wiley & Sons).


## Appendix 1. Model adequacy checks for regression analysis

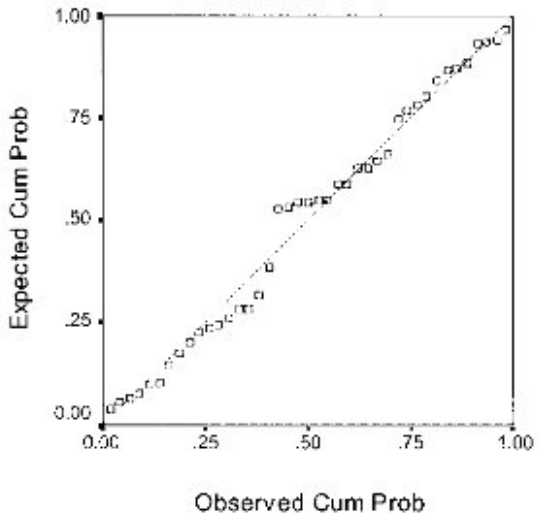



**Figure A1.** *Normal P-P plot of standardized residual. Dependent variable: actual hauteur.*

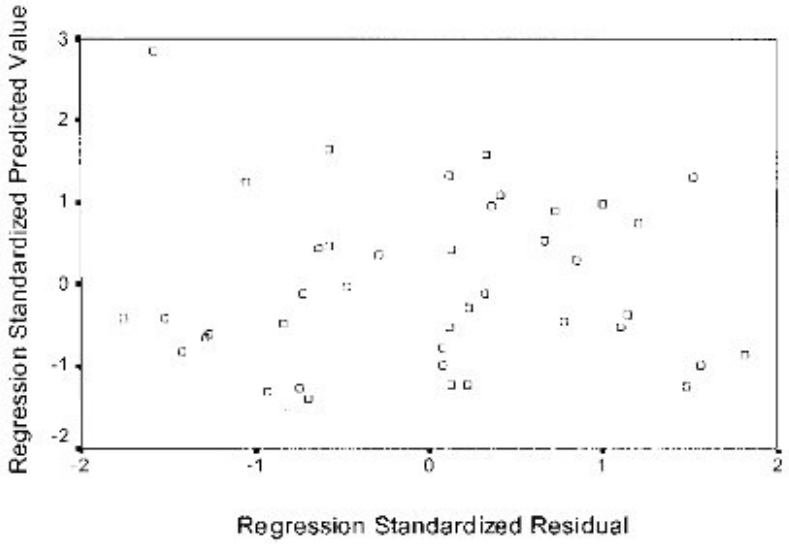



**Figure A2.** *Scatterplot. Dependent variable: actual hauteur.*

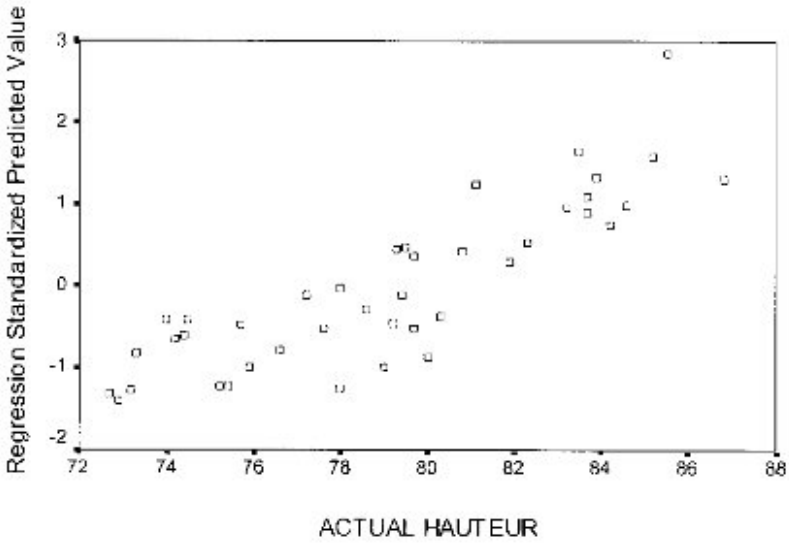



**Figure A3.** *Scatterplot. Dependent variable: actual hauteur.*