AUTEX Research Journal, Vol. 6, No 2, June 2006 © AUTEX

MATHEMATICAL MODEL FOR VIRTUAL DRAFT SYSTEM SIMULATION (VDSS)

A. E. Amin [*],A. S. Al-Geiheini [**], I. A. El-Hawary [**]

* Textile Department, Mansoura University
** Textile Department, Alexandria University

Abstract

The textile sliver drafting process has a decisive influence on the quality of yarn produced, and from the point of view of system theory it is marked by non-linearity, distributed delays and highly oscillatory disturbance response. As with most other textile manufacturing processes, this process has received almost no attention in control engineering literature. Motivated by the current needs of textile manufacturing, this paper introduces a suitable mathematical model of virtual draft system simulation.

1. Introduction

Although control engineering literature includes a vast body of papers on chemical engineering or aerospace applications, the textile industry processes have mostly been neglected. One factor contributing to this situation may be the fact that old low-production textile machines achieved satisfactory product quality with very simple control. However, the increasing productivity of modern textile machines and ever-tightening product quality specifications make the application of modern control approaches necessary. The present paper is a contribution to this development. It focuses on modelling and control of the textile sliver drafting process(particularly of cotton). This process is of key importance because the low irregularity of drafted sliver is essential for the production of high-quality yarn. This process is also interesting from the viewpoint of system theory. It is a non-linear system with distributed delays and a highly oscillatory disturbance response.

Although the drafting process has been subject of several books and papers, they offer little useful information for control design. Most books such as this recent monograph [2] discuss many aspects of drafting, but they do not propose any model suitable for control. There have been some attempts to find a mathematical model ([1], [6] and references therein) but these models are only partial. The influence of disturbance (input sliver linear density) on the controlled variable (output sliver linear density) is modelled, but the relation between the manipulated and the controlled variable is neglected. This has an even worse drawback. The drafting process is stable, but these models are not. Their instability has not even been noted in most papers (the only exception is [6]), as they were tested only in the frequency domain.

The present paper goes one step further; it analyses the source of the numerical problems and proposes alternative models with better numerical properties. One alternative is a non-linear model with distributed delays computed numerically using quadrature approximations. Another option is a rational model obtained by taking the dominant poles from the infinite spectrum of irrational transfer function. This second option is used as a basis for designing an internal model controller.

2. Mathematical model of the VDSS

The following assumptions are made:

1. The fibres are initially supposed to be ideally separated, and the correlation coefficient between the shears and fibre lengths is supposed to be negligible.
2. The standard loss of the fibre in cross-section will be found, instead of the standard deviation.

We divide all the fibres of three representative cross-sections into groups of (nearly) equal lengths, and consider one of these groups. the group represented in Figure 1 according to Vasilieff [7] is shaped like a parallelogram, the front and rear ends of the fibres having equal shears.

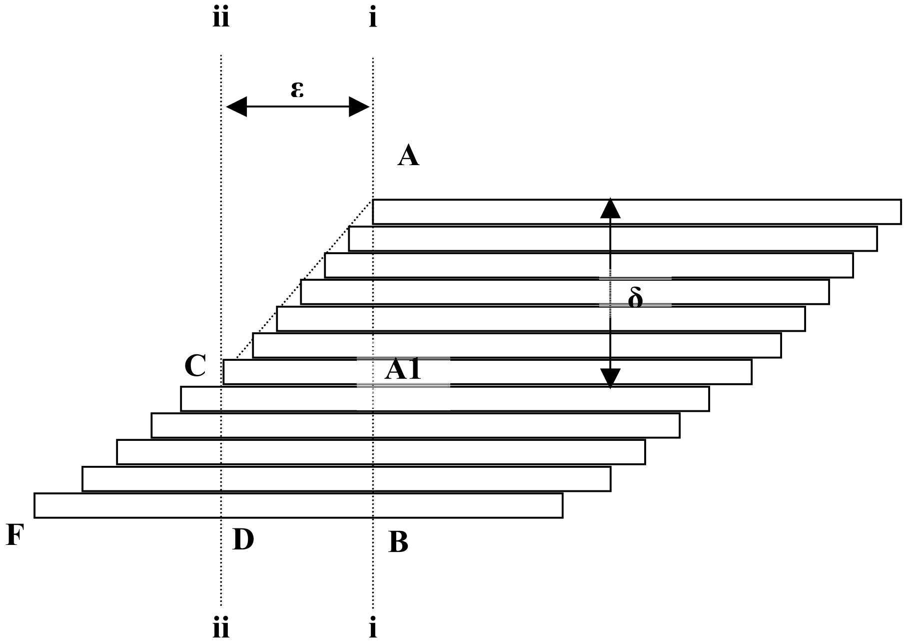


Figure 1. Fibres lost in cross-section

2.1 General formulae

$$V^2 = \frac{1}{n}\left[V_o^2 + AN_o(Z-1) + BN_o(Z-1)^2 Z\right]$$

where V is the irregularity, n the number of doubling, Vo the irregularity of the feeding product, and A and B the coefficients, the first due to the increasing irregularity from the reduction of thickness or decrease in the number of fibres in the cross-section, the second due to the drafting process itself, i.e. from the drafting mechanism; No the count of feeding product, and Z the draft .

2.1.1. Coefficient A

$$A = \varphi \frac{10^4}{N_f}$$

where φ is the coefficient of fibre association, Nf the number of the fibre.

Table 1.

Machine	1st. passage	2nd. passage	3rd. passage
φ	50	30	18

2.1.2. Coefficient B

$$B = \gamma^2 \varphi \frac{10^4}{N_f}\left(1 + 3C_f^2\right)\beta$$

where N_f is the coefficient characterising the drafting conditions, i.e. bad or good conditions, including the construction of the drafting mechanism, the thickness of the product etc. from Table 2; Cf the irregularity of the fibre lengths, and β the coefficient of settings.

Table 2.

Frequency curve assumed	1	2	3	4
γ	0.288	0.205	0.181	0.152

2.1.3. Coefficient of β

$$\beta = \frac{1}{\frac{1}{\beta_1} + \frac{1}{\beta_2} + \frac{1}{\beta_3} + \ldots\ldots\ldots\ldots}$$

where β_1, β_2, β_3,… etc. are the coefficients for 1,2,3 etc. pairs in the order of movement of the product.

This kind of irregularity increases with the following factors:

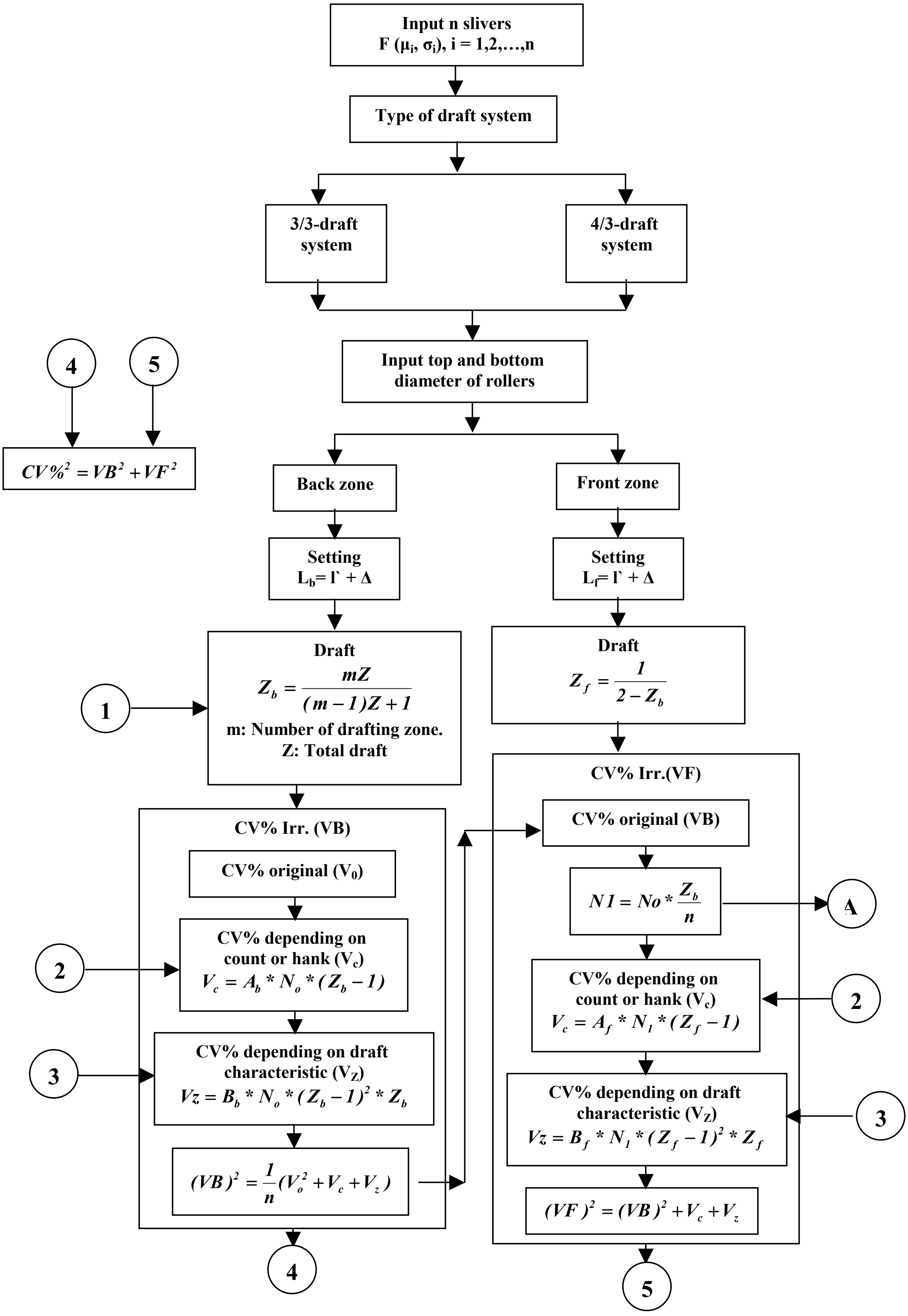
- i. Fibre association φ.
- ii. Coarseness $\frac{1}{N_f}$, and the irregularity of fibres in their length C_f.
- iii. The difference between settings and fibre length $\left(L - \bar{l}\right)$.
- iv. The draft Z.
- v. The hank number (or count) delivered N.

There have been several attempts to simulate a drafting system. The first attempt to resolve this problem was made by Hlava [3, 4]. The proposed linearised model with irrational transfer function is stable, and is in relatively good agreement with the responses from real processes (although the testing is not yet complete, due to technical problems with sensors). However, it was found thanks to continued experiments that this model is numerically ill-conditioned, and longer simulations lead to unreliable results.

The author has begun to construct the first virtual draft system simulation model [8] suitable for computer implementation. In this model the affected factors in the irregularity can be studied.

3. Mathematical model algorithm

Figure 2 shows the empirical algorithm for the draft system simulation model, as well as the software algorithm used in the virtual draft system model. Figure 3 shows the software algorithm for the virtual draft system simulation model.


Input n slivers
F (μ_i, σ_i), i = 1,2,…,n
Type of draft system
3/3-draft system
4/3-draft system
Input top and bottom diameter of rollers
Back zone
Front zone
Setting $L_b = \Gamma + \Delta$
Setting $L_f = \Gamma + \Delta$
Draft $Z_b = \frac{mZ}{(m-1)Z+1}$
m: Number of drafting zone.
Z: Total draft
Draft $Z_f = \frac{1}{2-Z_b}$
CV% Irr. (VB)
CV% original (V_0)
CV% depending on count or hank (V_c) $V_c = A_b * N_o * (Z_b - 1)$
CV% depending on draft characteristic (V_Z) $Vz = B_b * N_o * (Z_b - 1)^2 * Z_b$
$(VB)^2 = \frac{1}{n}(V_o^2 + V_c + V_z)$
CV% Irr.(VF)
CV% original (VB)
$N1 = No * \frac{Z_b}{n}$
A
CV% depending on count or hank (V_c) $V_c = A_f * N_1 * (Z_f - 1)$
CV% depending on draft characteristic (V_Z) $Vz = B_f * N_1 * (Z_f - 1)^2 * Z_f$
$(VF)^2 = (VB)^2 + V_c + V_z$
$CV\%^2 = VB^2 + VF^2$
1
2
3
4
5
2
3
4
5

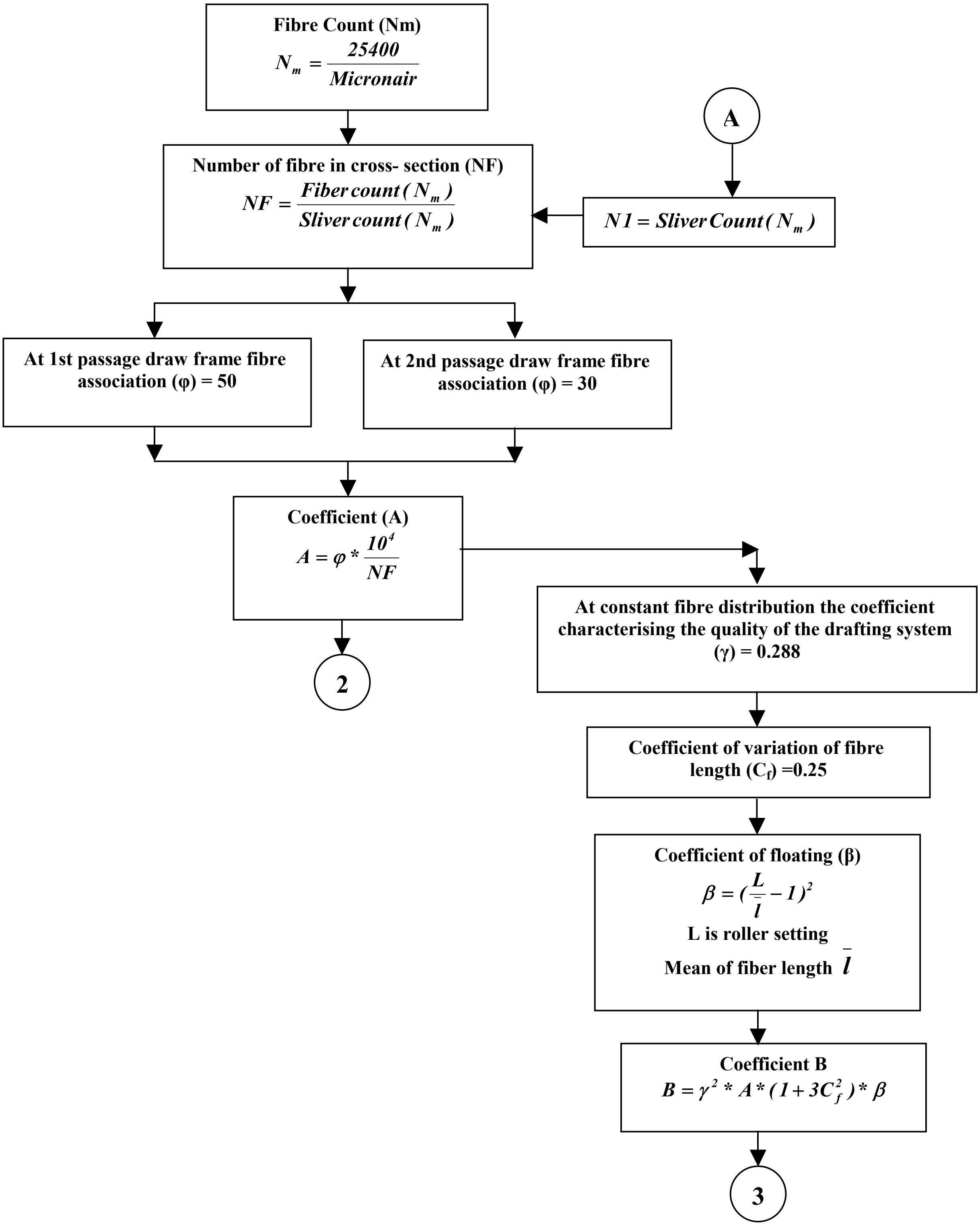


Figure 2. Mathematical algorithm for draft system model

```
Begin
{constant:
 Vo = I/P sliver coefficient of variation
 Micronair = μ;
 Draft = D;
 $C_f$ (Fibre coefficient of variation) = 0.25;
 Average fibre length = l;
 Setting = L;
 j= No. of roller pairs;
 { Function calculate coefficient A
 Nm(f) = 25400/ μ ;
 O/P Sliver Count = Nm(S)
 n (No. of fibre ) = Nm(f)/Nm(S);
 If M/c is 1st. passage Then ?phi= 50
 Else If M/C is 2nd. Passage then ?phi= 30;
 End if
 A= ?phi * 10^4/ n
 }
 { Function calculate coefficient β
 i= 1 to j
 H= $L_i$ / l;
 $\beta_i$=(H – 1)^2 + $C_f$ ^2
 Next i
 β=Σ (1/ $\beta_i$);
 }
 { Function calculate coefficient B
 If case FCA = 1 then k=0.288;
 Else If case FCA = 2 then k= 0.205;
 Else If case FCA = 3 then k= 0.181;
 Else If case FCA = 4 then k= 0.152;
 End If
 GAMA = k^2;
 B= GAMA * A * (1+3* $C_f$ ^2)* β;
 }
 {main program
 V1=A*Nm(s)*(D-1);
 V2= B* Nm(s) * (D-1)^2 * D
 V^2= (1/n)*[ Vo^2+V1+V2];
 }
 }
End.
```

Figure 3. Software algorithm for draft system model

4. Experimental work

In this part, the virtual draft system simulation is capable of detecting the CV% evenness value. Sliver quality is evaluated by the virtual draft system simulation model considering the type of fault. As shown in Figure 4, the charts illustrate the faults which may been found in the spinning mill.

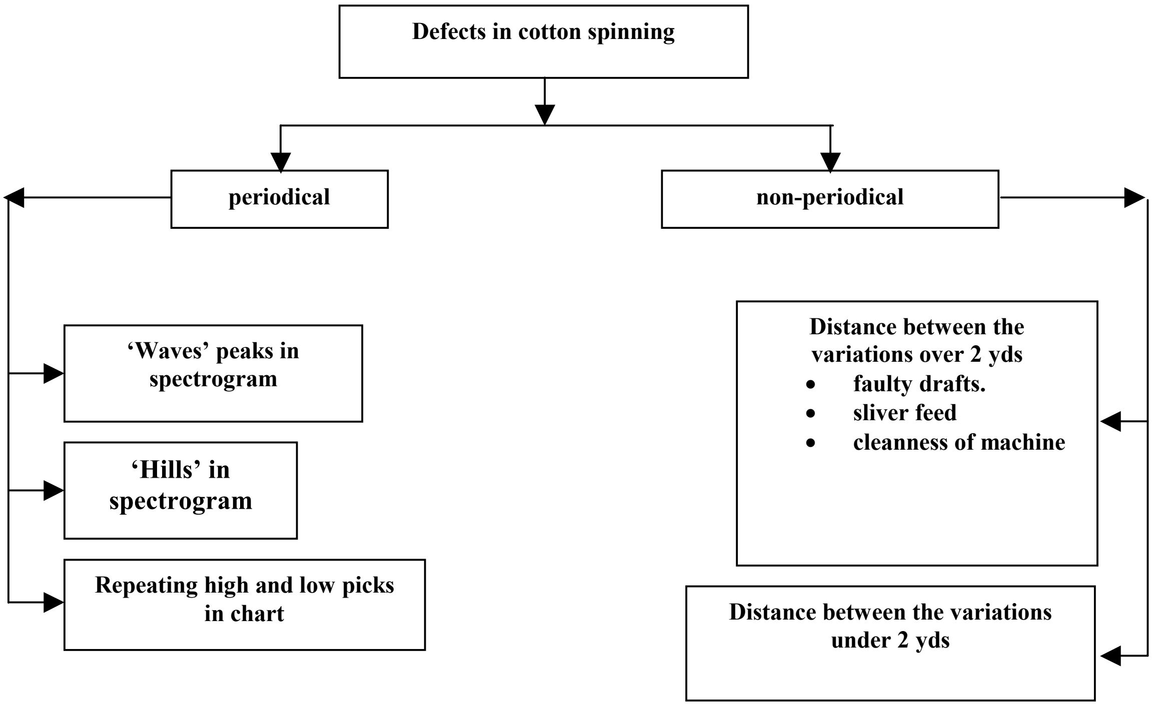
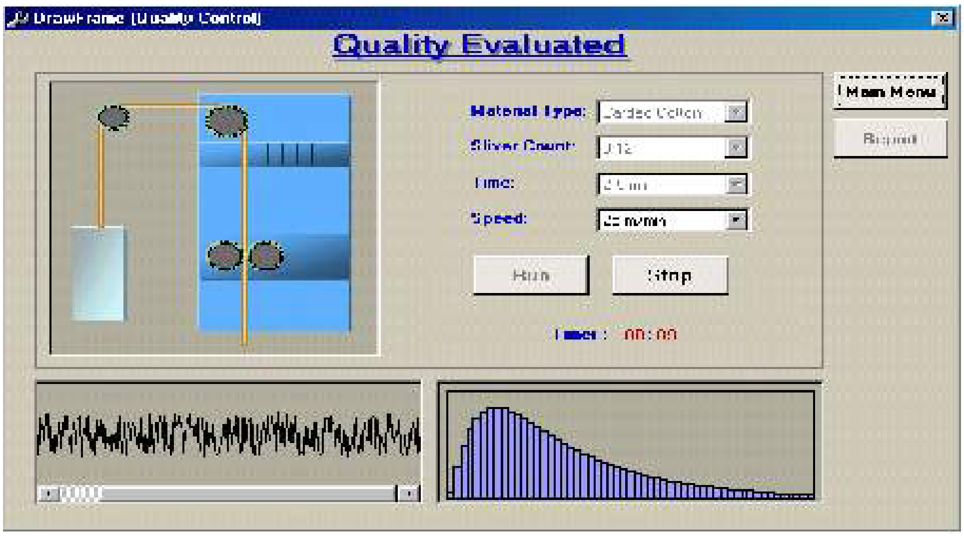


Figure 4. Chart illustrating fault types

5.Result and discussions

As shown in Figure 5, the distribution of sliver evenness is shown in the mass diagram and checking the periodic or drafting wave faults from spectrogram.



Material Type: Carded Cotton

Sliver Count:

Time:

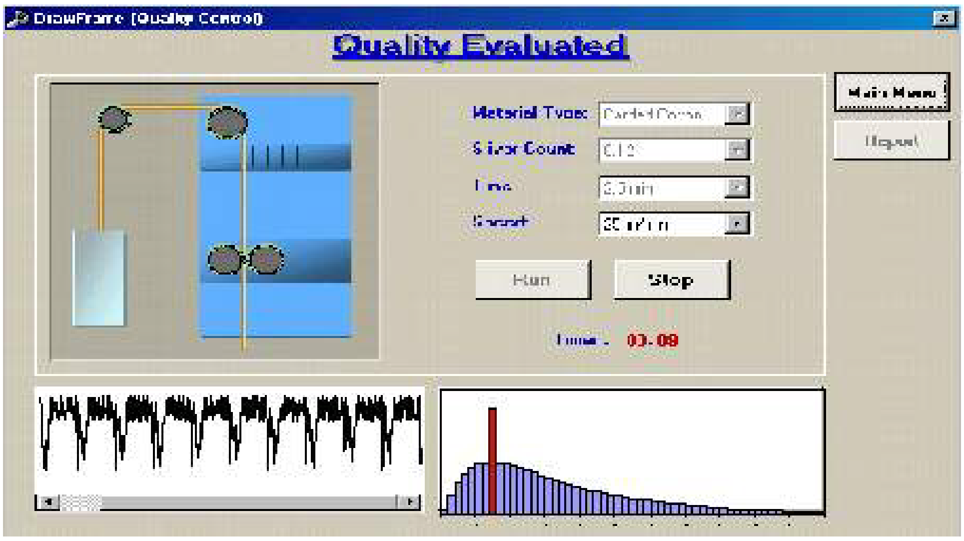
Speed:

Figure 5. Sliver quality evaluated

The figures illustrate the faults which are found in the drafting system. For some examples it has been possible to show the diagram and spectrogram, in order to demonstrate the effect of the fault.

Influence of Roller eccentricity

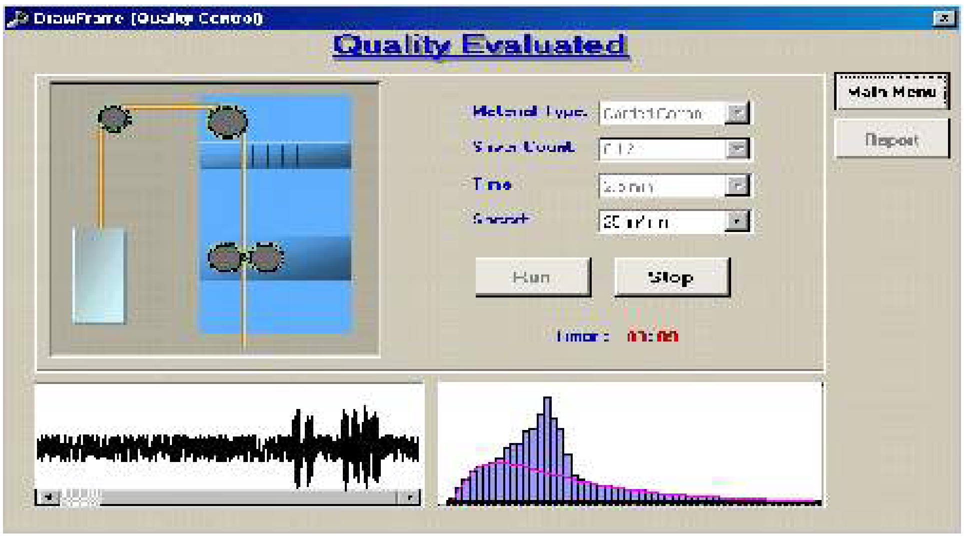
Only eccentric running rollers have been referred to where, for each full revolution, a periodic fault is produced. Worn-out and badly-ground rollers can also be oval in shape. In this case a faulty draft is produced twice per full revolution of the roller. Figure 6 shows the effect of an eccentric roller on the mass variation of a fibre assembly.



Material Type: Carded Cotton
Sliver Count: 0.12
Time: 2.5 min
Speed: [illegible]
Timer: 00:09

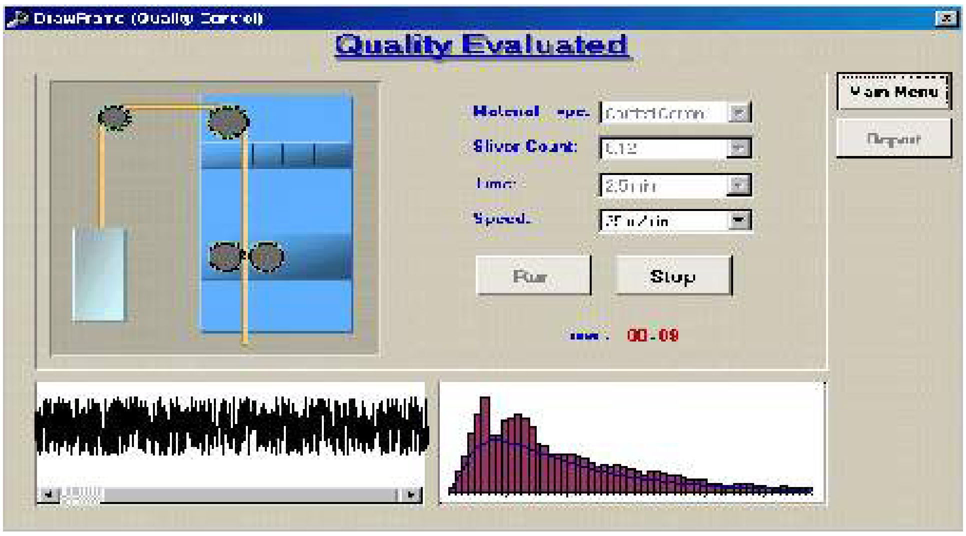
Figure 6. Effect of an eccentric roller

Influence of difference between settings and fibre length



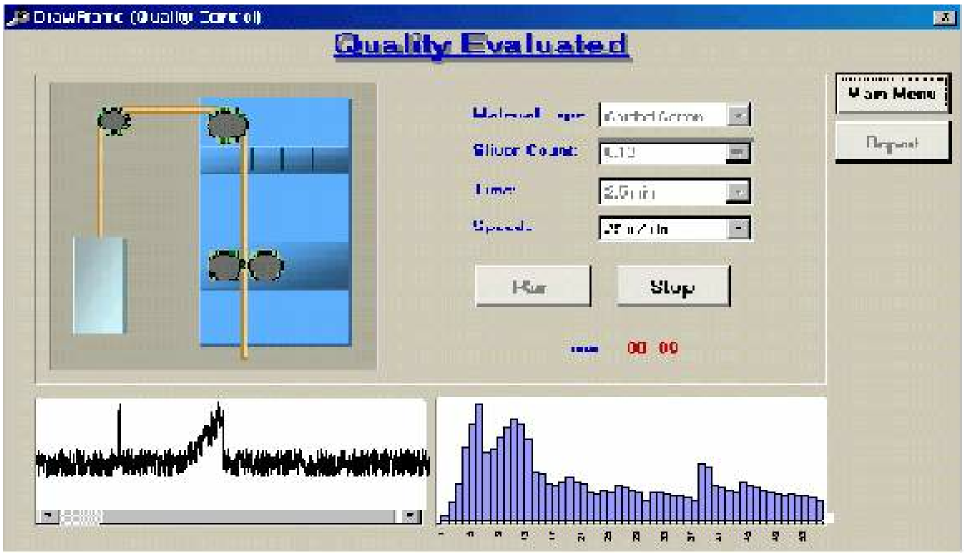
Material Type: Carded Cotton
Sliver Count: 0.12
Time: 2.5 min
Speed: [illegible]
Timer: 00:09

Influence of draft distribution



Material Type: Carded Cotton
Sliver Count: 0.12
Time: 2.5 min
Speed: [illegible]
Timer: 00:09

Influence of count variation



6. Conclusions

This paper has further elucidated the problem of mathematically modelling the textile sliver drafting process. The source of numerical problems with previously proposed models was explained, and we have shown how to design models with better numerical properties. These models were used as a basis for internal model controller synthesis. This paper can be considered as one of the first steps for applications in virtual draft system modelling for use in textile simulation engineering processes.

References

1. *S. N Djiev, Modelling a Double-Zone Drafter as an Object of Control, Textile Research Journal, Vol. 64,. No. 8., 1994, pp. 449-456.*
2. *P. Grosberg, and C. Iype, Yarn Production - Theoretical Aspects, The Textile Institute, 1999.*
3. *J. Hlava, Time Delay Systems Applications in Textile Industry – Modelling of Sliver Drafting Process, Preprints of 4th IFAC Workshop on Time Delay Systems, France, September 2003, CD-ROM*
4. *J. Hlava, Internal Model Control of Textile Sliver Drafting Process, Preprints of the 14th International Conference on Process Control, Slovakia, June 2003, CD ROM.*
5. *P. Novak, Modelling of drafting process from the viewpoint of sliver irregularity transformation, PhD Thesis, TU Liberec, Faculty of Textile Engineering, 1995.*
6. *A theory of drafting and its practical applications, Textile Journal of the Textile Institute, Vol. 45,. No. 3., 1954, pp. 167-267.*
7. *Amin. A.E., "Development of a simulation draft system model for virtual educational environment", under publishing.*

∇∆