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Approach Development for Surveillance Assistance: Spinning Mill Application

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ABSTRACT

Monitoring the state and the efficiency of cleaning and carding equipment is a good method of determining if the equipment is operating properly to get a better understanding about the actual machine performance. The paper attempts to develop and prove different empiric formulas to determine the partial efficiency index of spinning machines (machines of blowroom and cards) such as: Cleaning efficiency, Nep increase efficiency, Nep removal efficiency, Percent short fiber efficiency, Tenacity efficiency and Length efficiency. The implicit goal is to be able to evaluate the global efficiency index of various spinning machines by taking into account these different partial efficiency indexes. In addition, we proposed establishing an approach "Dynamic Method put in Scale (DMS)" which is an attempt to combine two techniques: objective reasoning and mathematical formulas to solve many complex system problems, especially when a system is difficult to model and control by a human operator or expert. We used the DMS to determine the global index efficiency, in order to solve a spinning problem by evaluation of the cleaners and simulating the efficiency for the different process stages during the treatment.

Keywords: Spinning, Blow room, Card room, Global efficiency, Dynamic Method with Scale (DMS).

I. Introduction

Since the industrial revolution and the factory systems for the manufacture of cotton yarns and fabrics more than 200 years ago, there has been need to describe the quality of the raw material and the global efficiency of machines. In the meantime, cotton production had been increasing considerably since mechanical harvesting had been introduced, and the production of ginning machines and spinning plants was increased accordingly. Thus, the spinner had to clean the cotton more aggressively and more intensively in order to achieve an equal visual level of cleanliness [1-8].

Consequently, many complications can occur during the spinning. Therefore, it is important to understand in details what happens throughout the machines efficiency in order to improve the quality of yarn [2, 9-10]. So, the spinner must be in a position to follow the state of machines, particularly with the intention of forecasting the spinnability of the fibre and the specified yarn quality without waiting for results on finished products [6].

Although, various methods found in the literature are very interesting, the global efficiency index of various spinning machines are not fully understood [3-6, 11-12]. Therefore, these previous studies are considered insufficient and unable to give a total description of machine results because of the other parameters such as raw materials have not been assessed [12]. For such high levels of complexity, fuzzy logic could be used. Indeed, the fuzzy logic provides an alternative solution to non-linear control since it simulates reality better. Non-linearity is handled by rules, membership functions, and the inference process resulting in improved performance, simpler implementation, and reduced design costs [13-16].

Nevertheless the fuzzy logic suffer from some limitations with respect to sensitivity. The primary difficulty in using fuzzy logic is that the programmer must first thoroughly understand the intricacies of and be able to precisely define a problem, and then must be able to evaluate and fine-tune the results [17]. So; fuzzy logic systems are not entirely analytic and thus involve fine-tuning, are unstable. Because of the rule-based operation, although defining the rule base quickly becomes complex if too many inputs and outputs are chosen for a single implementation since rules defining their interrelations must also be defined [14]. The number and complexity of rules depends on the number of input parameters that are to be processed and the number fuzzy variables associated with each parameter. One of consequences of this subjectivity is the risk of no-convergence of the defuzzification algorithm the undefined unforeseen measure [15].

We need to develop another method to emulate our ability to reason and make use of approximate data to find precise solutions. In this paper, we present an approach "Dynamic Method with Scale (DMS)" based on the techniques of fuzzy subsets. The DMS makes it easier to conceptualize and implement control systems and enable engineers to configure systems quickly without extensive experimentation. This method was applied to determine the global efficiency index in order to estimate the behaviour of cottons at the cleanliness for a better follow-up of the cleaners, and to avoid complaints formulated in the reception of the finished article. For this, it is necessary to determine the input variable (partial efficiency index) and output variable (global efficiency index).

II. Presentation of the machines

Spinning industry is composed of different rooms (in our study, we are interested of the blowroom and card room). Blowroom installation (each cleaning line) contains three cleaners connected in series to obtain the desired cleaning result (Figure 1).

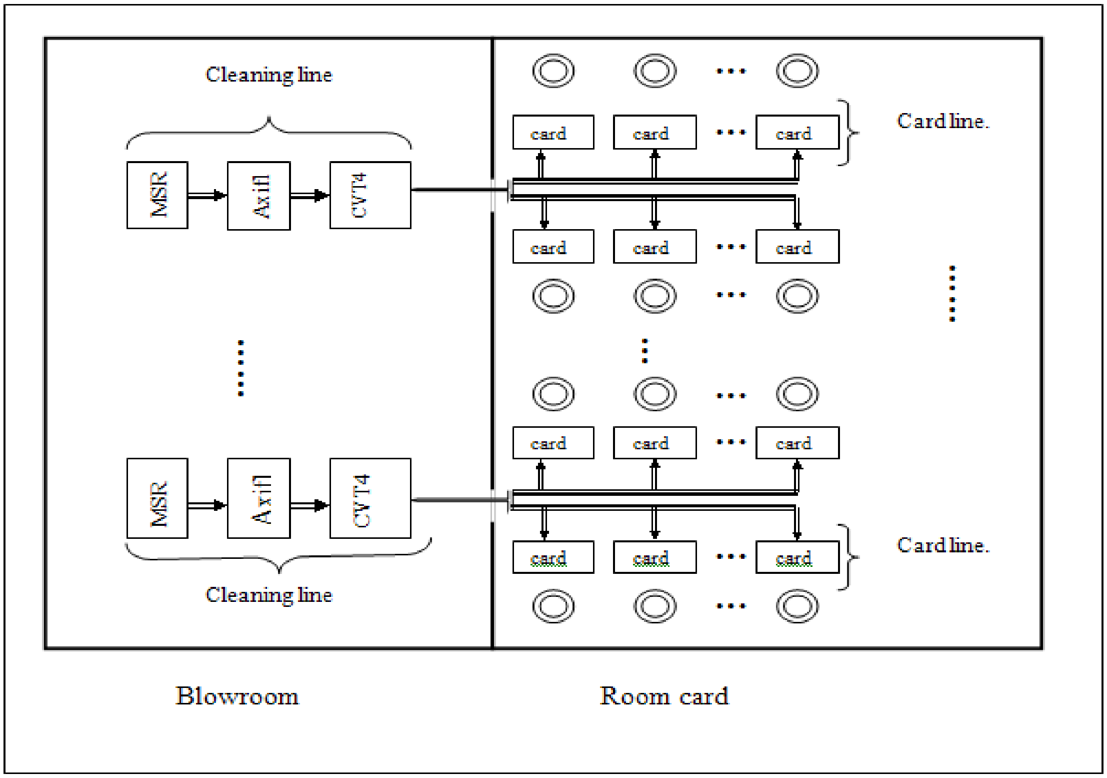
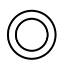


Figure 1. Presentation of the machines

 Pot: Stocking of the card sliver

The cleaners MSR, Axiflo and CVT4, eliminate impurities and increase the number of neps in the cotton (Cotton fiber neps are defined to be entanglements of several fibers, are not a genetically occurring property in seed cotton). Cotton processing machines that mechanically work the cotton fiber from bale to yarn are designed with the intent of minimizing fiber damage. Thus the material is passed over several rolls, each of them running at a higher speed and having finer clothing. Passage from one cleaner to the next takes place in the transfer mode ensuring a gentle treatment of the fibers. Due to the increasing speed the material is subjected to ever-higher centrifugal forces, i.e. the cleaning and opening efficiency increases from cleaner to cleaner. Impurities can be extracted from the fiber stock at the mote knives, provided on the periphery of the rolls [11].

Nevertheless, opening, cleaning and blending equipment shorten the staple length while increasing short fiber content and neps. Carding and combing reverse this by removing a percentage of the short fibers and neps. The basic purpose of this study is to use the AFIS (To measure the neps we used the USTER® AFIS neps (cnt/gr)) and the HVI to improve performance of the spinning process. Since the various mechanical processes modify the state of the fibers, we must first determine the different partial efficiency index of spinning machines.

III. Determination of the global index

The raw materials and the technological process influenced the final yarn quality. With machine settings and speeds optimized, a comparison of the fiber properties of stock-in compared with stock-out provides valuable information for achieving further optimization. However the yarn quality is improved when the cotton is easy to clean (good cleanability) and when the cleaning efficiency of the machine is improved. Therefore, the spinners are generally confronted to the problems of evaluation of the state and the efficiency of their machines without waiting for finished products result. The variation of the cleaning results do not limit itself to the influence of the impurities elimination efficiency according to the machine's types and work conditions such as quality of card's clothing, speeds, regulations, etc. Thus, it is very interesting to determine characteristic that informs on the easiness or the difficulty to rid trash from cotton in order to foresee his future behavior in cleaning and offer a preview on the cleaning efficiency of machines, to predict the results of cleaning processes [12].

We needed the global index to give an idea about the state of functioning of different machines. This global index is influenced by several fiber properties and often solved by considering the different partial efficiency index of spinning machines such as: Cleaning efficiency, Neps increase efficiency, Neps removal efficiency, Percent short fibers efficiency, Tenacity efficiency and Length efficiency.

III-1: Cleaning efficiency (Mcl)

Raw cotton contains various impurities as leaf, bark, and seed coat particles. Impurities content from bale to silver should decrease through the opening. Indeed, the requirements of sliver quality impose that the cotton must be intensively cleaned during ginning, spinning mill and carding [2-8]. On the other hand, the amount of these contaminations is useful information for finding more efficient cleaning processes and predicting the quality of the finished products.

The degree of cleaning Dcl is influenced not only by the lint characteristics in intermediate products, but also by the mechanical handling of the fiber, because cotton has a lower degree of cleaning D_{cl} if it is difficult to clean (poor cleanability (C)) and\or if the machine has a lower cleaning efficiency. However the degree of cleaning Dcl is improved when the cotton is easy to clean (good cleanability (C)) and\or when the cleaning efficiency of the machine is improved (equation 1) [12, 18].

$$D_{cl} = 10 \times C \times T \times M_{cl}$$

Equation 1

$$D_{cl} = \frac{T_i}{T_{total}} \times 100$$

T_i: Percentage of eliminated impurities.
T_{total}: Percentage of impurities at the input of machine.

"High cleaning efficiency" is regarded as a positive attribute, so, 100% say a goal (100%) of zero resultant impurities ($T_i = T_{total}$), therefore 0% announces that there is no elimination of impurities, so T_i = 0%) [18]. Another important factor is the trash content T of the cotton at the input of machine, the degree of cleaning for dirty cotton is more elevated than clean cotton on the same machine and in the same conditions.

III-2: Neps increase efficiency and Neps removal efficiency (MNi and MNr)

One of the main problems of yarn quality is its neppiness. Neppiness influences the appearance of yarn, and consequently the quality of fabrics especially dyeing uniformity [2,11-12]. Neps are created by the mechanical handling and cleaning of the cotton fiber, neps increase throughout the ginning, opening and cleaning process. Although there is a decrease during carding and combing, both are designed to align fibers and remove imperfections such as neps [19-21]. It is a recognized, however, that certain cottons tend to nep more easily than others when they are mechanically handled under identical conditions. Degree of increasing (blowroom) of neps D_{Ni}, can be defined by the following formula [21]:

$$D_{Ni} = \frac{C_{Ni}}{M_{Ni}}$$ Equation 2

$$D_{Ni} = \frac{Nb_{nepsout} - Nb_{nepsin}}{Nb_{nepsin}} \times 100$$; $Nb_{neps\ out} \geq Nb_{neps\ in}$

C_{Ni}: increase ability of neps
C_{Nr}: removal ability of neps
Nbneps in: number of neps per gram at the input of machine
Nbneps out: number of neps per gram at the output of machine

In the case of blowroom we note an increase of neps. The Degree D_{Ni} gives an idea on the neps increasing, thus, 0% of DNi (is regarded as a positive attribute) significant zero increase in corresponding neps (Nbneps out = $Nb_{neps\ in}$). According to Uster [22], it is possible to classify the degree of neps increasing, determined by equation (2), as indicated in Table 1[21].

Table 1. Classification of D_{Ni}%

Class (%)	Interpretation
≥ 80	Very bad
60-80	Bad
40-60	Average
20-40	Good
≤ 20	Very good

Thus, the more cotton has a tendency toward the formation of neps (C_{Ni} is big) the more DNi is raised. But the better the conditions of the machine (M_{Ni} is big), the less there is a formation of neps. So D_{Ni} is reduced (blowroom) [21]. Degree of removal (card room) of neps D_{Nr}, can be defined by the following formula [21]:

$$D_{Nr} = M_{Nr} \times C_{Nr}$$ Equation 3

$$D_{Nr} = \frac{Nb_{nepsin} - Nb_{nepsout}}{Nb_{nepsin}} \times 100$$; $Nb_{neps\ out} \leq Nb_{neps\ in}$

M_{Ni}: neps increase efficiency
M_{Nr}: neps removal efficiency

In the case of card room we note a decrease of neps, 100% say a goal (100%) of zero resultant neps (0 announces that there is no elimination of neps, so $Nb_{neps\ out}$ = $Nb_{neps\ in}$). According to Uster [22], it is possible to classify the degree of neps removal, determined by equations (3), as indicated in Table 2 [21].

Table 2. Classification of D_{Nr}%

Class (%)	Interpretation
≥ 90	Very good
80-90	Good
70-80	Average
60-70	Bad
≤ 60	Very bad

The more the neps are easily eliminated (C_{Nr} is big) and the card is good because it eliminates more neps (M_{Nr} is big), the more D_{Nr} is better. Therefore, yarn nepiness is a result of quality, processed raw materials and the technological process [21]. Although, the global efficiency depends essentially on the cleaning and neppiness results, we have to do a complete global efficiency study of spinning machines (machines of blowroom and cards) to know what physical properties modification could arise to the cotton. These physical properties are translated at the tenacity, short fibre count and length.

III-3: Percent short fibers efficiency, Tenacity efficiency and Length efficiency (Mfs, Mte and Mle)

Despite technology, rigorous mechanical processing remains a necessity in order to successfully open and clean, because the removal of impurities and neps (case of the card room) is usually accompanied by shortening of the length distribution, fibre breaking, fibre failure and other damages (increasing of short fibers, decreasing of tenacity and decreasing length) [9-10]. Therefore, all mechanical processing is a compromise between quality improvement (disentanglement and cleaning of fibres) and damage, which is defined as degradations of fibre's quality. This is necessary in order to establish a spinning mill's benchmark data.

To give a total description, it would be interesting to analyze the changes of physical properties for the successive spinning process machines. In order to express the degree of physical properties Di (percent short fibers efficiency (D_{fs}), tenacity efficiency (D_{te}) and length efficiency (D_{le}), the theoretical relation between the cotton ability and machine efficiency by analogy with the equation (1), concerning the elimination of impurities was derived.

The following formulas can be defined:

$$D_{fs} = Q_{fs} \times M_{fs} \quad \text{Equation 4}$$

$$D_{te} = Q_{te} \times M_{te} \quad \text{Equation 5}$$

$$D_{le} = Q_{le} \times M_{le} \quad \text{Equation 6}$$

Dfs: Degree of percent short fibers.
Dte: Degree of tenacity.
Dle: Degree of length
Qfs: Quality index of percent short fibers.
Qte : Quality index of tenacity.
Qle: Quality index of length.

III-3-1: The degrees (D_{te}, D_{le} and D_{fs})

These parameters provide measures of degradations in fiber quality during the cleaning treatment. The result of the physical property variations, defined by Di (Percent short fibers, tenacity and length), can be calculated by the following formulas:

$$D_{fs} = \frac{SFC_{input}}{SFC_{output}} \times 100 \; ; \; SFC_{output} \geq SFC_{input}$$

SFC_{input} (SFC_{output}): Percentage of short fibers at the input (output) of machine.

"High Degree of percent short fibers" is regarded as a positive attribute, so 100% of D_{fs} significant zero increase in corresponding short fibers (SFC input = SFC output). Therefore, more the Dfs is low, the more short fibers are obtained. Also, the greater the efficiency of machines (M_i) and the quality of raw materials (Qi) are bad, the more cotton has a tendency toward the formation of short fibers (Dfs is low) after cleaning (Equation 4).

$$D_{te}\left(D_{le}\right)=\frac{\textit{Tenacity (length) input}}{\textit{Tenacity (length)output}}\times 100$$

Tenacity (length) $_{output}$ ≤ Tenacity (length) $_{input}$

It becomes 100% when there is no decrease in corresponding tenacity, or when Tenacity (length) $_{output}$ = Tenacity (length $_{input}$. When the cotton has a lower tenacity, D_{te}, (or length D_{le}), if it is difficult to clean or the machine has a lower efficiency (M_i) (Equations 5 and 6).

III-3-2: The qualities (Qte, Qle and Qfs)

Give an idea about the future behavior of the raw material (Qi: Tenacity, length and percent short fibers) during the mechanical treatment.

Q_i = R x C

R: The tenacity value in the input machine
C: Cleanability

The more the cotton is easy to clean (good cleanability : C is big) and\or the tenacity is good (R is big), the more the quality (Qi) is better after cleaning.

Because all these factors usually vary simultaneously, it is very difficult to assess their individual influences on the spinning process. In order to get meaningful results of the functioning state of different cleaners, it is important to develop a method to estimate the global efficiency index and by taking into account the different partial efficiency index of spinning machines such as: Cleaning efficiency, Neps increase efficiency, Neps removal efficiency, Percent short fibers efficiency, Tenacity efficiency and Length efficiency.

IV. Principle of "Dynamic Method put in Scale (DMS)"

IV-1: General Presentation

DMS can control any types of linear systems that would be difficult or impossible to model mathematically. This method enables engineers to make use of information from expert human operators who have been performing the task manually. The DMS method can be decomposed in three steps: classification, inference and valorisation.

The basic idea consists to increasing the fuzzy subsets permitting to achieve stages of classification and valorisation. This increase permits a better precision of the output set evolution according to input sets. Also, the using of level-headedness coefficient provides a simple way to arrive at a definite conclusion based on input information.

IV-2: Classification Stage

IV-2-1: Determine the control system input

With DMS the first step is to understand and characterize the system behaviour. The primary objective of this construct is to map out the universe of possible inputs (classification) while keeping the system sufficiently under control. The classification function (K_i) is a graph of the participation magnitude of each input. It associates a degree of membership factor (μ) (degree of influence) with each of the inputs that are processed in order to define functional overlap between inputs.

Note: $K_i \in [1, n]$

n: Number of classes corresponds to the input variable (V_i) (for example in Figure 2, n=100)

IV-2-2: Stage of inference

Inference is a process that combines real values (V_i) (e.g., partial efficiency index of cleaner machine) with stored classification function data and a degree of membership to produce scaled input values. The degree of membership (μ) is determined by plugging the selected input parameter into the horizontal axis and projecting vertically to the upper boundary of the classification function (Figure 2).

By knowing, the two classes ($K_{i-1}(V_i)$ and $K_i(V_i)$) and their classification functions ($\mu(V_i, K_{i-1}(V_i))$ and $\mu(V_i, K_i(V_i))$) (Figure.2), we can determine the input scaled value $R(V_j)$ as follows:

$$R(V_j) = K_i(V_i)\ \mu(V_i, K_i(V_i)) + K_{i-1}(V_i)\ \mu(V_i, K_{i-1}(V_i)) \qquad \text{Equation 7}$$

$j \in [1, m]$
m: number of input variable
$V_i \in [Min, Max]$
Min; Minimum value of input variable
Max: Maximum value of input variable

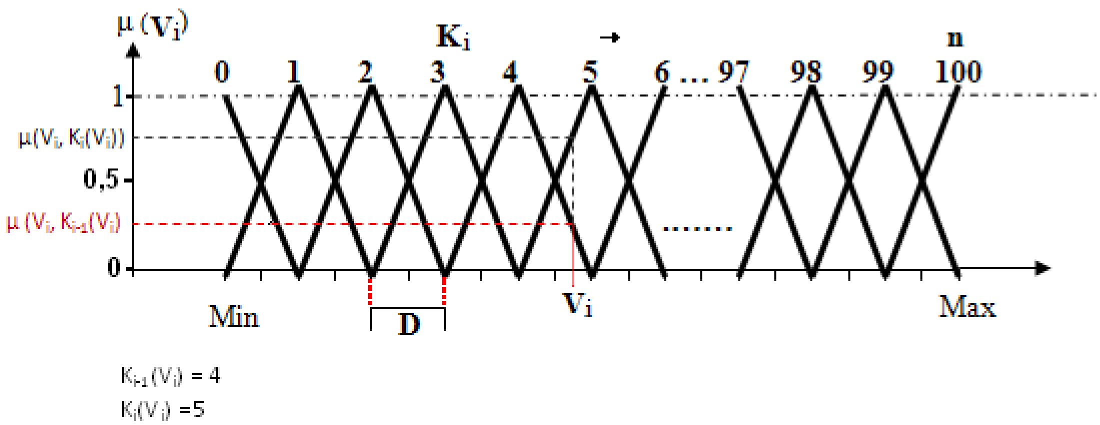


Figure 2. The features of a classification function

IV-2-3: Stage of valorisation

In the last stage the valorisation combines all its inputs, by using a formula, to obtain an output response Z. Indeed, the formulas use the level-headedness coefficient $b(V_j)$, determined from the expert human, as weighting factors to determine their influence on the final output conclusion. Once the input scaled value $R(V_j)$ and the level-headedness coefficient $b(V_j)$ associated to every input variable are defined, the output response Z can be defined by the following formula:

$$Z = \sum_{j=1}^{m} R(V_j) \times b(V_j) \qquad \text{Equation 8}$$

m: number of input variable

IV- 3: Mathematical development

We suggest a general mathematical reasoning from the DMS method to define the equation of:

- ✓ Every line segment, which delimits a corresponding elementary subset.
- ✓ A real value (R) put in scale after projection

IV-3-1: Presentation

In order to apply DMS to a particular system, the programmer must first make a "classified model," a set describing the system and how to handle it. Making such a model involves analyzing a problem and setting up the proper degree of membership to define it, a process called valorisation. The steps in building our system consists of graphical triangles that can help visualize and compute the input-output action.

Figure 2, illustrates the features of the triangular classification function, which is used due to its mathematical simplicity. These functions work fine and are easy to work with [17]. Indeed, narrow triangles provide tight control when operating conditions are in their domain, whereas wide triangles provide looser control (Figure 2).

Then, the division D was calculated by the following equation:

$$D = \frac{Max - Min}{n}$$

Min; Minimum value of input variable

Max: Maximum value of input variable n: Number of classes corresponds to the input variable (V_i) (Figure 2). For every value V_i Є [Min, Max] there is a projection on an increasing segment and another decreasing.

IV-3-2: Equation of the increasing segments (ΔK)

For K Є [1, n], Δ_K: $y = a\,x + b_K$:

This is the general increasing segment equation (these line segments have the same sloping because they are parallel) (Figure 3).

So

Therefore: $$a = \frac{1}{D}$$

Or, $y_1 = a\,x_1 + b_K$ ⟶ $b_K = y_1 - a\,x_1$

Therefore,

$$b_K = 0 - \frac{K - 1 \times D + Min}{D} = 1 - K - \frac{Min}{D}$$

For, K Є [1, n]

$$\Delta_K: y = \frac{x}{D} + 1 - K - \frac{Min}{D} = \frac{x - Min}{D} + 1 - K \qquad \text{Equation 10}$$

For, x Є [(K-1) × D + Min , K× D + Min]

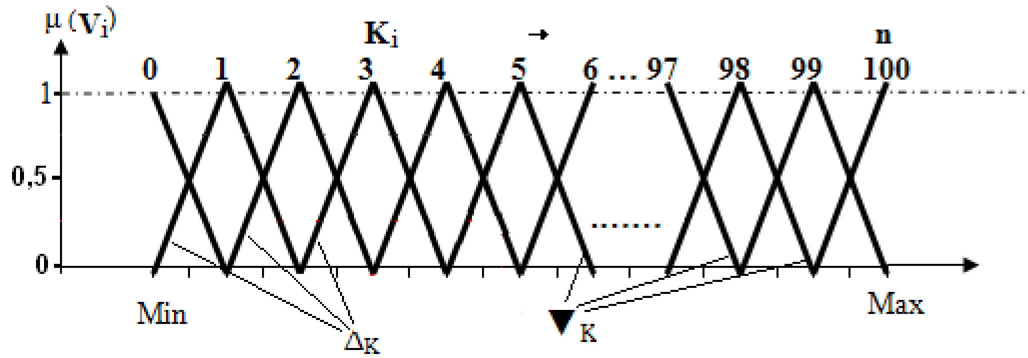


Figure 3. The increasing (ΔK) decreasing segments (▼K)

IV-3-3: Equation of the decreasing segments (▼K)

For K Є [0, n-1]

$▼_K$: $y = a\,x + b_K$:

This is the general decreasing segment equation (these segments have the same sloping because they are parallel) (Figure 3).

So $$a = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0 - 1}{K+1 \times D + Min - K \times D + Min}$$

Therefore, $$a = -\frac{1}{D}$$

Or: $y_2 = a\,x_2 + b_K$ ⟶ $b_K = y_2 - a\,x_2$ So:

$$b_K = 0 + \frac{K+1 \times D + Min}{D} = 1 + K + \frac{Min}{D}$$

For, K Є [0, n-1]

$▼_K$:
$$y = -\frac{x}{D} + 1 + K + \frac{Min}{D} = \frac{Min - x}{D} + 1 + K$$ Equation 11

For, x Є [K × D + Min, (K+1) × D + Min]

IV-3-4: Equation of the value put in scale after projection (R)

For every value V Є [Min, Max],

$K_\Delta = E\left(\frac{V - Min}{D}\right) + 1$ and

$K_{\blacktriangledown} = E\left(\frac{V - Min}{D}\right)$ E is the integer part

K_{Δ} and $K_{\blacktriangledown}$ are the classes associated to the real value V

Thus, the value put in scale R (V) can be calculated according to the following equation (Equation 7):

$$R(V) = K_{\Delta} \times \underbrace{\left(\frac{V - Min}{D} + 1 - K_{\Delta}\right)}_{\Delta_K(V)} + K_{\blacktriangledown} \times \underbrace{\left(\frac{Min - V}{D} + 1 + K_{\blacktriangledown}\right)}_{\blacktriangledown_K(V)}$$

For $S = \frac{V - Min}{D}$,

$$R(V) = \left(E(S) + 1\right) \times \left(S + 1 - E(S) + 1\right) + \left(E(S)\right) \times \left(1 - S + E(S)\right)$$

After simplification

$$R(V) = \frac{V - \text{Min}}{\text{D}} \quad \text{so} \quad R(V) = n \times \frac{V - Min}{Max - Min} \qquad \text{Equation 12}$$

DMS is a very suitable method to estimate the cleaning efficiency of machines. In accordance with equations (8 and 12), it is possible to quantify the global index of spinning machines. Table 3 summarizes the different partial efficiency index of spinning machines (cleaners and cards) and limits for each value (maximal value and minimal value) as well as their level-headedness.

Table 3. Different partial efficiency indices

Input variable	Symbol	Equation	Room	Minimal value	Maximal value	Level-headedness
Cleaning efficiency	**Mcl**	Dcl = 10 ×C ×T × Mcl (7)	blowroom	0,1	2	0,35
			Carding	2	8	
Neps increase efficiency	**MNi**	$D_{Ni} = \frac{C_{Ni}}{M_{Ni}}$ (8)	blowroom	0,3	3	0,3
Neps removal efficiency	**MNr**	DNr = MNr × CNr (9)	Carding	1	4	0,3
Percent short fibers efficiency	**Mfs**	Dfs = Mfs × Qfs (10)	blowroom Carding	2	5	0,15
Tenacity efficiency	**Mte**	Dte = Mte × Qte (11)	blowroom Carding	3	4,5	0,1
Length efficiency	**Mle**	Dle = Mle × Qle (12)	blowroom Carding	3	4,5	0,1

The coefficient attached to a partial efficiency index as its weight in the determination of global index involving weighting. The basis for proposing the weighting coefficients are data on the final yarn quality. So, this level-headedness enables us to make use of information from expert human operators (spinner) who have been performing the task manually.

This research was carried out in SITEX Company (Industrial Society of Textiles in Tunisia), thus these level-headedness are proposed by the expert spinner of this company. The spinners give more importance to: cleaning (0.35) and the rate of neps (Neps increase efficiency (0.3) in the case blowroom and Neps removal efficiency (0.3) in the case of card room) than physical properties (tenacity (0.1) , short fibre count (0.1) and length (0.1)) These coefficients can be exchanged according to the requirements of the spinning mill.

In the following, the authors present the results of the mechanical processing for different levels of mill cleaning, in order to judge and compare the efficiency of different cleaners and cleaning lines. Thereafter, in the further studies, we will try to develop software, named EFFITEX, to help the operator use the DMS method and supervise the state of machines. This software eases data analysis and gives the spinner the indications needed for decision making.

V. Conclusion

In order to produce competing products on international scale, the spinner need a new method at his disposal for the assessment of the raw material and of this machines, optimization the spinning process, forecasting running conditions in the mill and 'engineering' the required yarn quality based on the raw material data. Therefore, it is very interesting to develop feature characteristics, which give information about the future behavior of cotton in cleaning and gives a preview on the cleaning efficiency of cleaner and even a cleaning line.

In the present paper we determined the global efficiency index by taking into account the different partial efficiency index of spinning machines, while using the proposed empiric formulas, in order to get a better understanding about the actual machine performance. Then, the correlation between the partial and global efficiency of different cleaners were determined by using the DMS method.

DMS a powerful new way is used in system control and design analysis, because it shortens the time for engineering development. It is, however, best applied to systems with uncertainties:
With DMS we can describe the output as a function of any number of inputs linked with level-headedness coefficient. This method provides a way to approach a control problem. To make the data analysis easier for the operator, we developed, in the further studies, software, which enable the calculation of both partial and global efficiencies of every spinning machine.

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