

Optimization of specific energy consumption for compact-spun yarns

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A computer program has been designed to compute the value of the specific energy consumption in compact yarn spinning with variable spindle speed profile, considering all the spinning variables. It is proved that the specific energy has a minimum value at a defined spindle speed which depends on the yarn specifications, dimensions of the bobbin used, and speed profile. The program determines the value of spindle speed at which minimum specific energy is obtained. It is also found that the finer yarn count requires higher spindle speed and smaller ring diameter which leads to the minimum specific energy.

Keywords: Compact spinning, Cotton, Ring spinning, Specific energy, Traveller

1 Introduction

Compact yarn brought a revolution in ring spinning technology. In recent years, compact spinning technology has shown a rapidly developing technological trend in most countries. Compact yarns are claimed to be stronger and less hairy, and have higher yarn elongation, higher work of rupture, and lower yarn irregularity as compared to conventional ring-spun yarns¹. Different machine manufacturers are using different methods to condense the fibres emerging out from the front rollers; these methods are air dynamical, magnetic, and mechanical compact systems. As the result, the specific energy consumption of the compact yarns is higher than that of ring-spun yarns, especially due to principle of yarn formation. One of the challenges of the spinning industry is the power cost¹. Energy consumption is considered as one of the main factors affecting the operating cost, and in the present time, it increases at higher rate than the other variable costs. The problem of power requirements for textile industry, especially for the ring spinning machine, has been investigated by several researchers with the aim of finding the economical methods for its calculation¹⁻⁶. Soliman² analyzed the components of the power consumption of ring spinning machine. Catling and De Barr³ studied the power requirement for the cotton ring spinning machine. El-Sheikh and Soliman⁴ studied the power consumption for various

machines in spinning, weaving and knitting sections and deduced an empirical equations for estimating power at each stage.

El Messiry^{5,6} attempted to minimize the package power consumption. Ramsis *et al.*⁷ studied the factors affecting specific energy consumption for two-for-one twister machine. Other studies were done on management of power storage in spinning mill⁸. Krause and Soliman⁹ deduced empirical equations for calculating specific energy consumption for open end and ring spinning machine. However, the power requirements of compact spinning frames, the major part in a spinning mill, are expected to be elevated than that in the ring spinning.

Many studies^{10,11} have been carried out to determine factors affecting the energy consumption in ring spinning machines, and several improvements have been made in the design of spinning machine to increase spindle speed and efficiency of the machine. The manufacturers of modern compact spinning machines have reduced the ring diameter and the bobbin length, and increased the spindle speed up to 25000 rpm. Construction improvements of the different working elements of the ring spinning frame and optimized spinning frame geometry led to increase of productivity, better yarn quality as well as flexibility of the process. The study on power consumption is becoming more and more important owing to the modern trend towards higher spindle speeds and larger packages. Hence, the necessity of reducing the power requirements in ring spinning machine has increased with the introduction of long

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individual drive in spinning mills. In this study, the factors affecting the specific energy for compact yarns are considered for the determination of the optimum spinning conditions.

2 Materials and Methods

The power consumption was analyzed in a mill which produces combed cotton yarns for various applications with count range 40 - 160 Ne. The mill is provided with long ring and compact spinning machines with 1200 spindles capable to work with spindle speed up to 25000 rpm. The theoretical calculation of the specific energy (SE) for the spinning of compact yarns was done and compared with the measured values.

2.1 Analysis of Power Consumption in Compact Spinning

Several researchers²⁻⁹ analyzed the power requirement for ring spinning machine. Soliman² deduced the following equation for the determination of the power requirement for ring spinning machine:

$$N_{\text{total}} = N_s + N_p + N_n \quad \dots (1)$$

In the case of constant spindle speed, the elements of power requirement for ring spinning are given by

$$N_s = 4.25 \cdot Z \cdot G^{0.87} \cdot D_r^{1.7} \cdot n^{2.4} \cdot 10^{-8}$$

$$N_p = 0.53 \cdot D_r^{3.5} \cdot h \cdot Z \cdot n^{3.1} \cdot 10^{-9}$$

$$N_n = 3.33 \cdot Z \cdot g^{1.9} \cdot h \cdot n^{1.4} \cdot 10^{-7}$$

where N_s is the spinning power (kW); N_p , the package power (kW); N_n , the no-load power (kW); Z , the number of spindles; G , the traveller weight (mg); D_r , the ring diameter (cm); d , the bobbin diameter (cm); h , the bobbin height (cm); g , the spindle pitch (cm); and n , the spindle speed (thousands rpm).

The design of the compact ring spinning machine, in general, is similar to that of the ring spinning machine. However, more air suction is required to compact the fibres before entering the spinning triangle. In the above equations, the spindle speed is considered to be constant during the bobbin build which is not the case in the compact spinning, besides the use of high power fan for the broken end collecting system and compacting suction unit. Overhead cleaner with the high suction fan is usually needed and automatic doffing system is a must, especially for long spinning machines. All the above changes need more power which will be higher than that given by Eq. (1). Hence, power component (N_1) should be added. Figure 1 shows the analysis of power components of compact ring spinning machine.

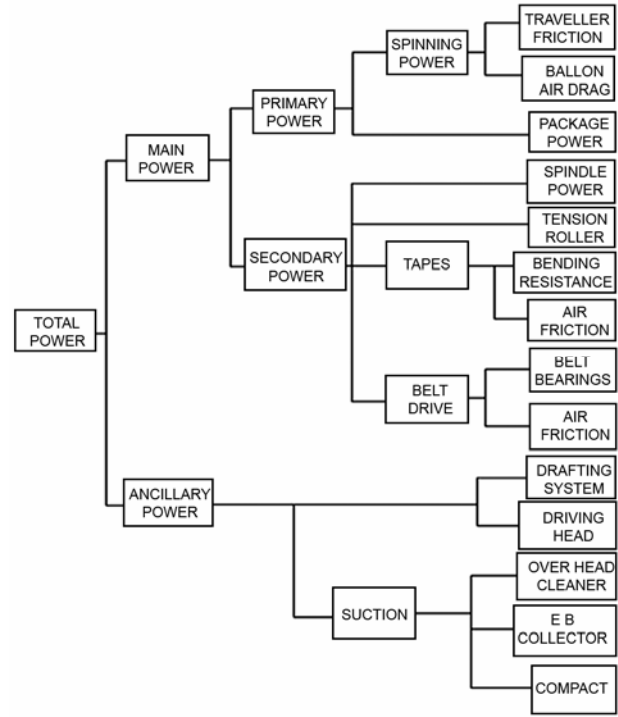


Fig. 1—Analysis of power components

Therefore, Eq. (1) of the total power can be rewritten as

$$N_{\text{total}} = N_1 + N_s + N_p + N_n,$$

where N_1 is the power of constant part (overhead cleaner power + suction power + doffing power) (kW).

Then

$$N_{\text{total}} = N_1 + k_1 n^{2.4} + k_2 n^{3.1} h + k_3 n^{1.4} h \quad \dots (2)$$

where k_1 , k_2 and k_3 are the constants that are equal to $4.25 \cdot Z \cdot G^{0.87} \cdot D_r^{1.7} \cdot 10^{-8}$, $0.53 \cdot D_r^{3.5} \cdot Z \cdot 10^{-9}$ and $3.33 \cdot Z \cdot g^{1.9} \cdot 10^{-7}$ respectively.

The input power calculation should take into consideration the average motor efficiency η . The specific energy will be

$$SE = N_{\text{total}} / \eta \cdot P$$

where P is the total production during calculated time kg/h.

In the case of variable spindle speed, the value of total specific energy consumption (SE) can be expressed as follows:

$$SE = [\sum (N_1 T_i + k_1 n_i^{2.4} T_i + k_2 n_i^{3.1} h_i T_i + k_3 n_i^{1.4} h_i T_i)] / \eta [\sum P_i T_i] \quad \dots (3)$$

where i is the 1, 2, 3... m ; T_i , the total building time for i^{th} part in h_i ; and n_i the spindle speed at i^{th} part in thousands rpm.

Figure 2 illustrates that the spindle speed is changed more than 25 times during the building of the bobbin, which means that m will be equal to 25. Thus, Eq. (3) can be used to get the value of SE considering the value of the n_i as an average spindle speed over each part, depending on the degree of accuracy required. The speed profile of the spindle with respect to bobbin height may be simplified by assuming that the spindle speed is linearly varied during the building of cop, body and nose, as shown in Fig. 3.

2.2 Development of Specific Energy Consumption Software (SECP)

Software package (SECP) is designed to provide a tool to calculate the value of the energy consumption for different spinning conditions. The application provides a simple user interface that allows entering the variables while presenting a visual guide to help understand the role of each variable, as shown in Fig. 4. The main output of this program is to calculate the power and specific energy consumed in compact spinning machine and deduce the maximum spindle speed which gives minimum specific energy, taking into consideration the variables of the spinning process and spinning machine design. The output of the application is graphically represented.

3 Results and Discussion

The main difference between the ring spinning machine and the compact spinning machine is the addition of the pneumatic suction in the drafting system in order to compact the spinning triangle in pneumatic compact system. This will increase the value of SE consumption of the ring spinning section. The measurements of the power consumption in the different sections of compact spinning mill producing yarn of count 60 Ne have been analyzed. It is found that the value of SE of compact ring spinning system represents 80 % of the consumed power for the whole mill.

3.1 Theoretical Analyses of Specific Energy Consumption of Compact Yarns

Considering that the spindle speed is varied according to speed profile as shown in Fig. 3, the values of specific energy for maximum spindle speed that ranges from 14000rpm to 25000 rpm for different bobbin heights are given in Fig. 5.

The analysis of the results indicates that percentage of increase for specific energy (SE) as a function of

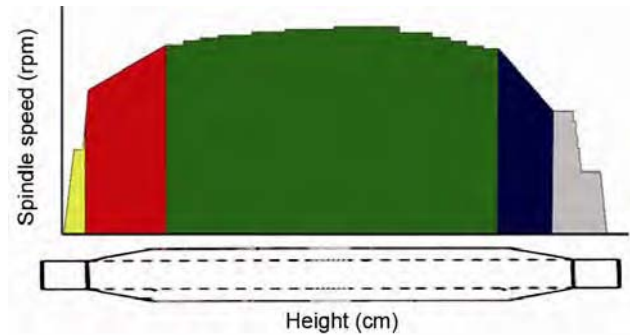


Fig. 2—Variation in spindle speed during bobbin build

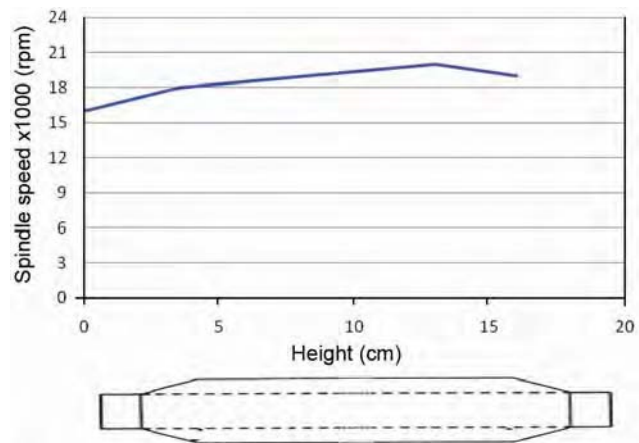


Fig. 3—Simplified change of spindle speed during bobbin build

bobbin height decreases with the increase of the spinning speed. However, the total SE is found to be dependable on the bobbin diameter and spindle speed as well as spindle speed profile during the bobbin build which is given in Eq. (3).

Further, computing of SE using SECP for different parameters is shown in Fig. 6 which indicates that the specific energy is depending on the yarn count and spindle speed. Hence, the finer the yarn count, the higher will be the specific energy. However, its minimum value of specific energy is obtained at a higher spindle speed than that in the case of the coarse yarn.

Figure 7 shows the effect of bobbin diameter and its height on the specific energy for yarn count 60 Ne using the practical ratio of (h/d_r) . It can be deduced that it is advisable to use ring diameter D_r of 34mm and bobbin height of 165mm for obtaining minimum specific energy at higher values of spindle speed. The above examples of calculations illustrate the necessity to estimate the value of specific energy in different spinning conditions.

Fig. 4—Specific energy consumption software (SECP) data entry form

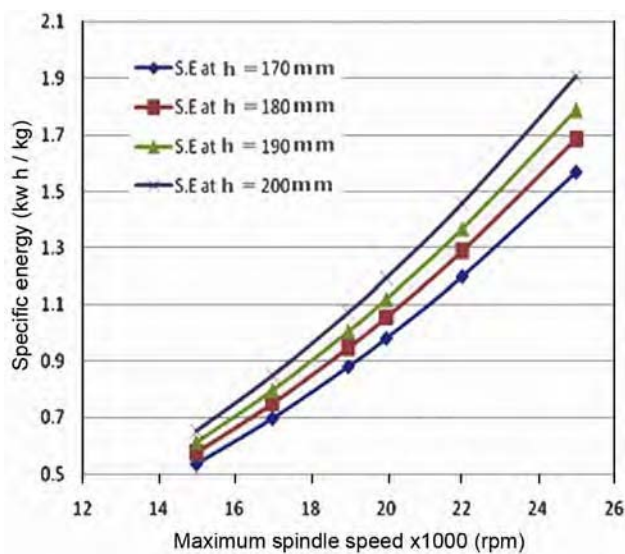


Fig. 5—Value of the specific energy versus spindle speed

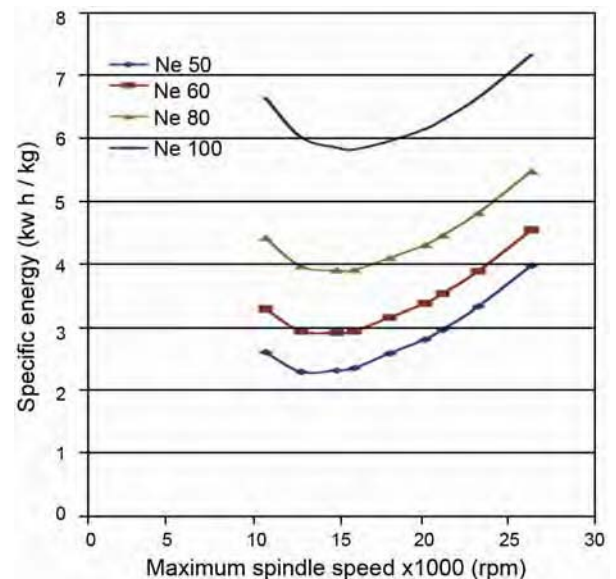


Fig. 6—Specific energy versus spindle speed for different yarn counts

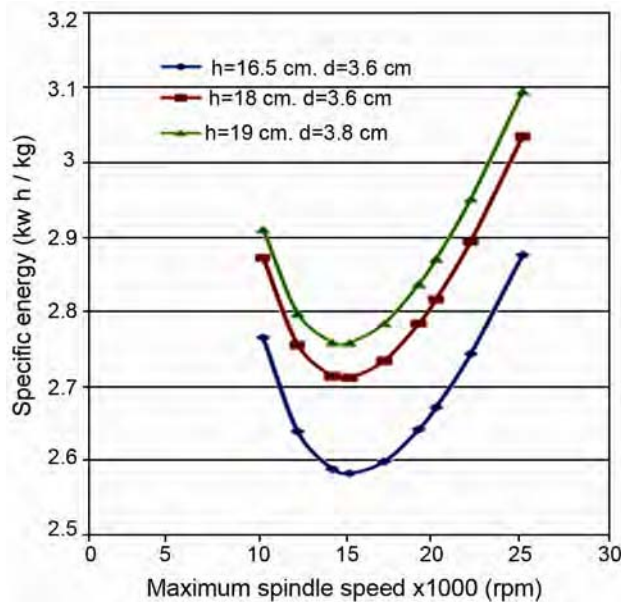


Fig. 7—Specific energy versus spindle speed for different bobbin dimensions for compact-spun yarn of 60 Ne, 36mm ring diameter, and 38mm ring diameter

3.2 Experimental Measurements of Specific Energy Consumption for Compact Yarns

In order to verify Eq. (3), several measurements of the power consumption have been carried out in running mill at different spinning conditions. A comparison of the specific energy calculated with Eq. (3) to that measured at the spinning mill for compact-spun yarn shows that the agreement is close, and therefore, Eq. (3) may be regarded as applicable. The value of the specific energy for compact-spun yarns is found to be higher as compared to the ring-spun yarns because of the use of the additional air suction unit for condensation of the fibres at the front zone. However, the difference depends on the yarn count and spindle speed. For the fine yarns and

high spindle speed the ratio is higher by 5% while for coarse count the ratio may reach 20%.

4 Conclusion

4.1 Eq. (3) can be used to calculate the specific energy of ring or compact spinning with the acceptable accuracy.

4.2 Computer program has been developed to calculate the value of the specific energy (SE) and its minimum value according to yarn specifications, spinning condition and bobbin dimensions.

4.3 For specific yarn, either compact or ring-spun, the value of maximum spindle speed should be chosen according to Eq. (3) in order to get the minimum specific energy using the developed software SECP.

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