Cost Optimization of a Ring Frame Unit

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Abstract India focuses on many sectors out of which much of its growth in energy consumption is expected to occur in the countries outside the Organisation for Co-operation Economic and Development (OCED) known as non-OCED where demand will be drawn by strong, long-term economic growth and India fits into this particular category. In this research, the spinning mill is considered for optimizing the parameters regarding the energy management with the real-time data taken from a ring frame unit of spinning mill, analysis is done to find the feasible operating conditions with the aim of minimizing the energy cost and increasing the profitability of the sector, thereby suggesting for the spinning mill sector in India.

Keywords Cost optimization · Doff time · Energy management
Ring frame unit · Spinning mill

1 Introduction

Energy is the lifeline growth for any economy. In the case of a developing country like India, energy sector is imperative because when considering the energy needs which are increasing day by day, huge investment is made in the view to meet the

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demand. Industrial sector energy use in the non-OCED economic countries including India is expected to increase by 1.8% per year compared to 0.6% per year in the OCED Economics [1–3]. The chasm in the growth rates mirrored both faster anticipated economic expansion outside the OCED and differences in comparison of industrial sector production. Industrial textile sector has an overwhelming presence in the economic life of the country as it is the second last provider of employment next to agriculture. The opening up of the Indian economy in 1991 gave the much needed thrust to the textile industry which has become one of the largest players in the world.

Textile industry of India ranks second in the world and also contributes 11% to industrial production, 14% to manufacturing sector, 4% to the gross domestic product (GDP) and 12% to the country's total export savings. About 35 million people are directly benefitted through employment and also to other 54.85 million people in its related activities [4–7]. High speed drives for textile rotor spinning applications are also considered. In this research a high speed drive and frictionless suspension system for a rotor spinning unit which opens up the field for further textile technology development, potentially leading to higher productivity, reduced power consumption and dust deposit are considered [8].

2 Energy Consumption Details of the Spinning Mill

The spinning mill taken for study consists of 30 ring frames of various counts. There are seven ring frames of the same count that corresponds to 21's count. Only one such ring frame is taken for analysis and is extended for the remaining spinning frames. The ring frame details, motor details are given in Table 1 and it shows the energy consumption of various units of the spinning mill considered.

It can be seen from Table 1, that more energy consumed in the ring frame section and second consumption comes to the preparatory section. Hence in this research a ring frame section is considered. Figure 1 shows the ring frame section taken for analysis. The ring frame section of Fig. 1 is operated at a speed of 17,000 rpm (average of 16,677 rpm) all the times to produce the yarn. For the analysis point of view, the speed of the spindle is varied and the major readings of

Table 1 Energy consumption details of various sections in a spinning mill

S. No.	Units	Energy consumed (%)
1	Spinning (ring frame)	44.21
2	Preparatory	29.42
3	Plant	11.60
4	Auto coner	8.65
5	Compressors	2.93
6	Lights	1.44
7	Others	1.75

Fig. 1 Ring frame section

Table 2 Readings of 1-doff of ring frame section

S. No.	Set speed (rpm)	Average speed (rpm)	Doff time (min)	Displayed yarn length (m)	Displayed production per spindle (g)	Energy consumed (units)	Production per doff (kg)
1	14,000	13,731	75	1589	44.68	33	52
2	15,000	14,975	69	1597	44.9	35	52.1
3	16,000	15,800	65	1589	44.68	36	52.2
4	17,000	16,625	62	1589	44.68	39	52.75
5	18,000	17,650	58	1589	44.68	42	55

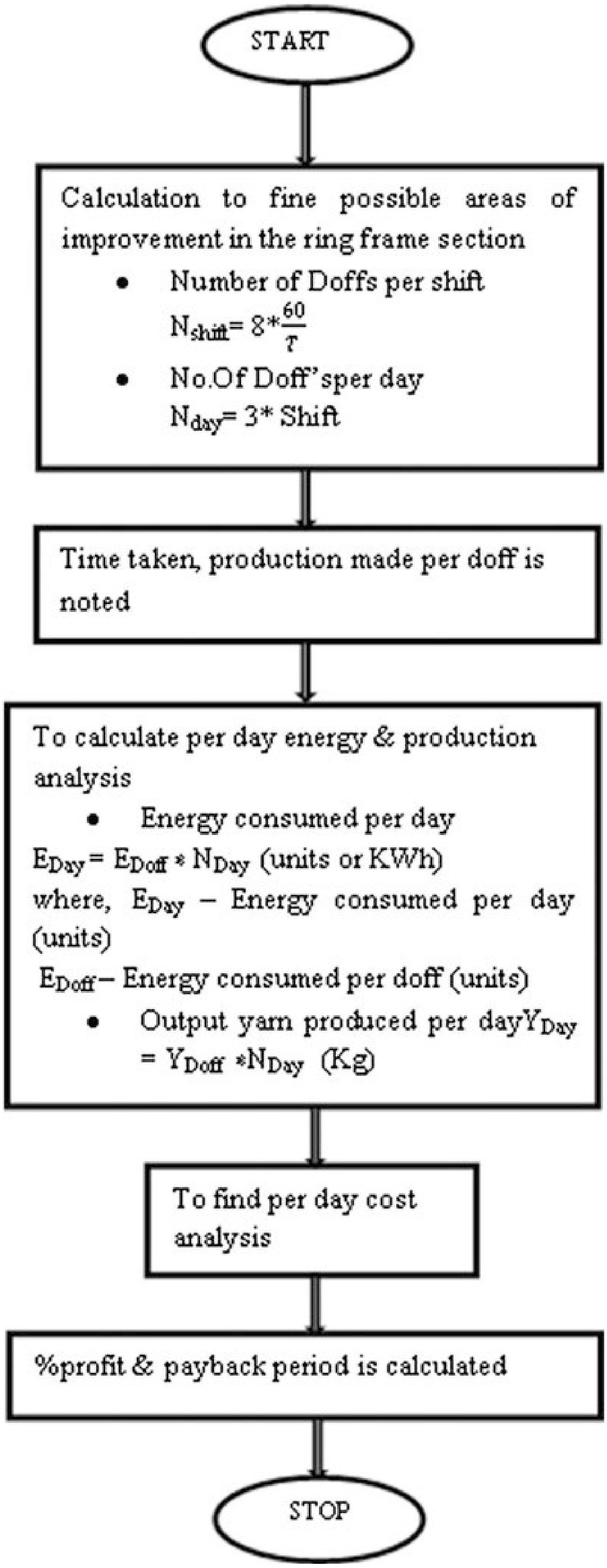
doff time, energy consumed and the production made are noted and tabulated in Table 2.

With readings noted down, the cost analysis of energy and the profitability of yarn are done to find the optimum point of speed of the ring frame to be operated with the ultimate aim of attaining higher profit of the spinning mill [9–11].

3 Per Day Mathematical Analysis

The generalized steps involved includes audit current operating conditions of the mill, collection of required identification of the areas that needs to be improved, plotting graphs and inferences and cost analysis. But in order to obtain a paramount cost analysis [12–15] view, a sequential flow chart may be followed is shown in Fig. 2.

Fig. 2 Flowchart of cost analysis



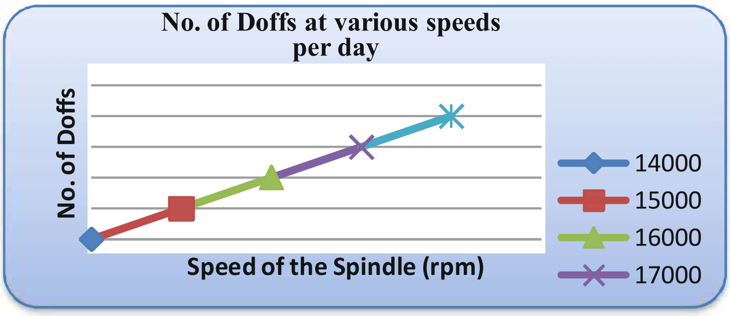


Fig. 3 Number of doffs per day

Table 3 Number of doffs at various speeds of the spindle

S. No.	Set speed (rpm)	Doff time (min)	Doff time, T (min) (approx.)	No. of doffs per shift, N_{Shift}	No. of doffs per day, N_{Day}
1	14,000	75	80	6	18
2	15,000	69	74	6.486	19.45
3	16,000	65	70	6.857	20.57
4	17,000	62	67	7.164	21.49
5	18,000	58	63	7.619	22.85

3.1 Per Day Energy and Production Analysis

With the measured readings of one doff at various speeds of the ring frame, the total production of yarn are calculated for one day and the respective graph is plotted and shown in Fig. 3. Table 3 provides the data for number of doffs per day.

It can be seen from Table 3 that extra 5 min is added to the doff time considering the replacement of the empty spindles in the ring frame after the production. It is noted that the number of doffs per day increases by one consecutively with the increase in speed by 1000 rpm. The minimum number of doffs is at 14,000 rpm (18th Doff) and the maximum number of doff is at 18,000 rpm (22nd Doff) of the spindle.

3.2 Total Energy Consumed and Total Production at Various Speeds of Spindle

Table 4, shows the total energy consumed and total production per day. Figure 4, shows the graphical representation of details mentioned in Table 4. The total energy consumed (units) by the ring frame increases as the speed of the spindle (rpm) increases. From the energy saving point of view, the spindle should be operated at a speed of 14,000 rpm (which consumed energy of 366 units less than in 18,000 rpm

Table 4 Production per shift and per day

S. No.	Set speed (rpm)	Energy consumed per doff (units)	Energy consumed per shift (units)	Energy consumed per day (units)	Production per doff (kg)	Production per shift (kg)	Production per day (kg)
1	14,000	33	198	594	52	312	936
2	15,000	35	227.03	681.08	52.1	337.95	1013.84
3	16,000	36	246.85	740.57	52.2	357.94	1073.83
4	17,000	39	279.40	838.21	52.75	377.91	1133.73
5	18,000	42	320	960	55	419.05	1257.14

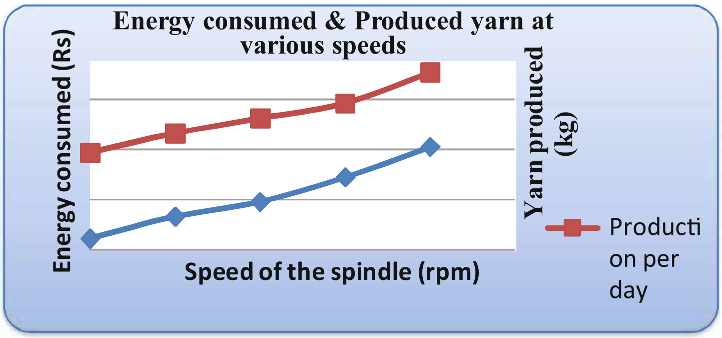


Fig. 4 Energy consumed at various speeds

Table 5 Units consumed per kg

S. No.	Set speed (rpm)	Energy consumed per day (units)	Production per day (kg)	UKG
1	14,000	594	936	0.635
2	15,000	681.08	1013.83	0.672
3	16,000	740.57	1073.82	0.690
4	17,000	838.20	1133.73	0.740
5	18,000	960	1257.14	0.764

per day). The production of the yarn is high at higher speed of the spindle (298 kg increase of yarn produced at 18,000 rpm from a base speed of 14,000 rpm). Therefore, from the productivity point of view, the ring frame should be operated at a speed of 18,000 rpm to yield higher kg of yarn.

3.3 Units Consumed per kg (UKG) Analysis

Table 5 shows the units consumed per kg of yarn and Fig. 5, show the corresponding graphical representation of details mentioned in Table 5.

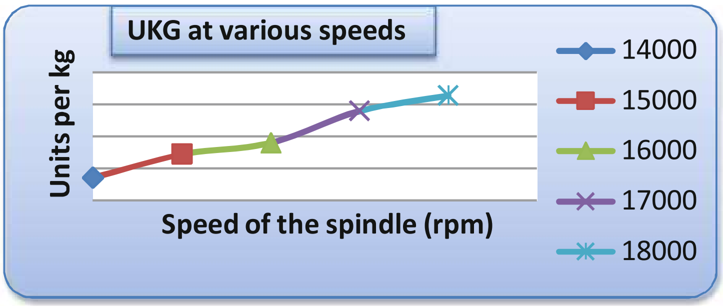


Fig. 5 UKG at various speeds

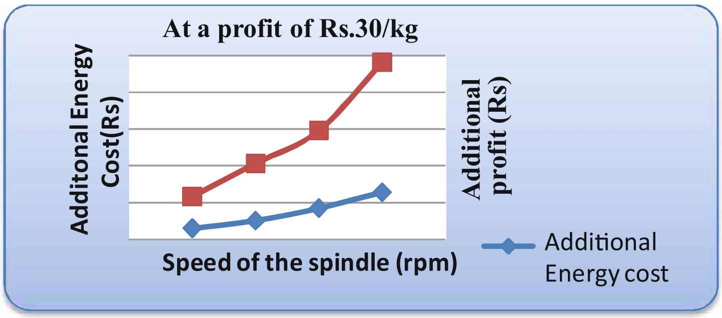


Fig. 6 At a profit of Rs. 30/kg

It can be seen that energy consumed per kg of yarn increases gradually as the speed of the spindle increases [16–18]. It consumes 143 Wh more energy at the highest speed (18,000 rpm) per kg of yarn.

3.4 *Per Day Cost Analysis*

For cost analysis, two major factors are considered

(i) Energy cost per unit
(ii) Profit of the yarn per kg

Also the following details are taken.

(i) The average cost of energy per unit from various sources (Tamil Nadu electricity board, wind units, third party MALCO thermal and wind units of India) of the spinning mill is taken as Rs. 7(Indian Currency)
(ii) The profit per kilogramme of the yarn has the range of Rs. 5, 10, 15, 20, 25 and 30 based on various market conditions.
(iii) 14,000 rpm is taken as the reference value for analysis.

The additional energy costs (Rs.) and profit per day is shown in Appendix 1. Table 5 shows the calculated value at a profit of Rs. 5/kg of yarn and Rs. 30/kg of yarn. Additional profit and additional energy costs are calculated for Rs. 5, 10, 15, 20, 25, 30/kg of yarn. Figures 6 and 7 shows the graph corresponding to Rs. 5/kg and Rs. 30/kg of the yarn.

Fig. 7 At a profit of Rs. 5/kg

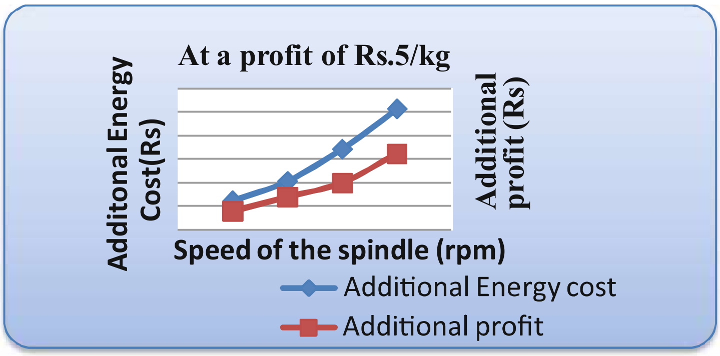
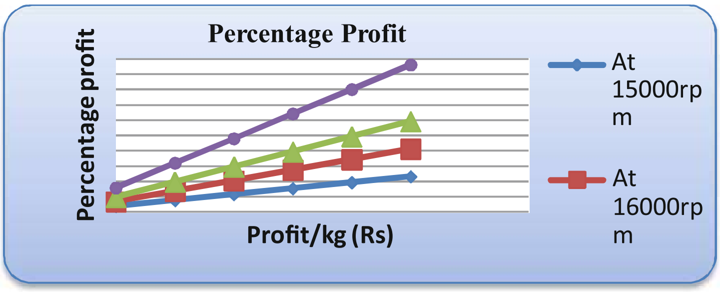


Fig. 8 Percentage profit



4 Results and Discussion

From per day mathematical analysis provided in previous sections with the manual interpretation, it can be seen that when the profit of the yarn is Rs. 5/kg, the additional energy consumption cost is greater than the additional profit for the speed greater than 14,000 rpm (considered as the base value for analysis). When the profit per Kilogramme of yarn is Rs. 10, it is found that the additional profit becomes more than the additional energy cost for all speeds greater than 14,000 rpm of the spindle. The ring frame was operated at its full load with 17,000 rpm of the spindle speed. In order to operate at 18,000 rpm, it is suggested to replace the existing three phase induction motor with a higher rated machine. The payback period (approximate) is calculated and shown in Eq. (1)

$$\text{Payback period} = (\text{Motor price} + \text{Installation charge})/\text{Annual savings}. \quad (1)$$

The additional profit of the yarn for a year (Annual savings) when the spindle is operated at 18,000 rpm is found to be around Rs. 11 lakh. The total price of the new high rated motor around Rs. 7 lakh(inclusive of interest value and installation charges) without considering the utility rebate cost, the payback period is found to be seven months (approximately) when the profit/kg values is calculated and Fig. 8 shows the percentage profit at various speeds of the spindle.

It can be seen from Fig. 8 that there is a huge profit increase at 18,000 rpm speed of the spindle than the other speed. For the available seven ring frames of 21's count the profit analysis for 18,000 rpm is estimated (approximately) for various profit/kg (Rs.) values and tabulated in Table 6.

Table 6 Profit per kg

S. No.	Profit per kg (Rs.)	Additional profit at 18,000 rpm (Rs.) (approx.)
1	5	40 lakh
2	10	80 lakh
3	15	1 crore
4	20	1 crore and 50 lakh
5	25	2 crore
6	30	2 crore and 40 lakh

5 Conclusion

From the cost analysis performed with the real time data, it is clear that there will be loss, if the ring frame is operated at a higher speed (15,000 rpm and above) when the profit of the yarn/kg is Rs. 5. If the operating speed is 17,000 rpm, there may be a loss about Rs. 700 per day (about Rs. 250,000 a year) as the additional energy cost exceeds the additional profit. Also a large amount of energy can be saved by operating at 14,000 rpm.

If profit less than Rs. 10/kg then,
Operate the spindle at 14,000 rpm
else,
If profit greater than Rs. 10/kg then
Operate the spindle at 18,000 rpm

Payback Period:
Example: From the annual cost analysis when the profit is Rs.10/kg and the speed of 18,000 rpm, the payback period for the replacing motor is calculated as follows.
The annual savings for 18,000 rpm is Rs. 1156628. Approximate value of Rs. 1100000 is taken. Then from the price of suggested motor mentioned above,
Payback period = 700000/1100000
= 0.63 years = 7 months (approx.).

Appendix 1

The additional energy cost (Rs.) at various speeds is calculated by subtracting the respective actual energy cost with the energy cost value of 16,000 rpm.

Example: Taking the energy cost of 18,000 rpm from Table 5, the additional energy cost is calculated as:

$$\text{Additional energy cost} = 6720 - 4767 = \text{Rs. } 2562$$

Similarly for the Additional energy consumed (units), Additional production (kg) and Additional profit (Rs.) are calculated for various speeds with the reference values of 16,000 rpm.

The profit per day is calculated as:

$$\text{Profit per day} = ((\text{Profit/kg}) \times \text{Production per day}) = \text{Rs. } 5369.14$$

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