Optimization of Spindle Speeds in Ring Frames

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Received 18 June 1984; accepted 4 September 1984

The economics of higher spindle speed of the ring frame has been assessed under the operating conditions in Indian mills. Equations have been derived for arriving at the economics of increasing spindle speeds when there is no restriction on the availability of power as well as during power shortages. It has been shown that an increase in spindle speed will invariably lead to more savings; only if there is no gross profit margin, higher spindle speeds will not be economical. On the other hand, when there is a power shortage, a reduction in speed, the extent of reduction being a function of the quantum of power shortage and count, would lead to an increase in overall production and to higher savings.

An increase in spindle speed offers a number of advantages to a mill, like reduction in overheads and administration and wage costs per unit production as well as higher marginal profit accruing from the increased sales. As against this, certain speed-related costs such as power, consumption of ring frame components, ring frame tenter wages and working capital as well as fixed assets would tend to increase with spindle speed. The overall economics would be determined by the balance between these two items of cost.

Economics of Higher Spindle Speeds

A general expression for arriving at the economics of increasing spindle speeds has been derived here. The various components of spinning costs fall under the following three heads, when any increase in spindle speed is contemplated:

Variable costs—Under this category fall the costs which vary directly in proportion to spindle speed such as raw material, the entire post-spinning wages, and part of spinning wages, power costs for preparatory, post-spinning and packing departments.

Fixed costs—These costs generally remain fixed and comprise part of spinning wages, administration, depreciation, interest and overheads.

Speed-related costs—These costs are related to the spindle speed and include ring frame power costs, stores components, tenter wages and capital.

The profit per spindle per year in Rs $(P_e)$ in any given mill running at a spindle speed of $s$ is given by:

$$P_e = (R - V - S - F)$$  \(1\)

where $R$ is the sale value per spindle per year; $V$, the variable costs per spindle per year; $S$, the speed-related costs per spindle per year; and $F$, the fixed costs per spindle per year, all values being in rupees.

An increase in spindle speed from $s$ to $(1 + x)s$ would produce the following increases in these cost components:

- $R$ becomes $R(1 + x)$
- $V$ becomes $V(1 + x)$.

$S$, the speed-related costs, has four components, viz. the ring frame power cost $(p)$, the stores costs $(r)$, ring frame tenter wages $(t)$, and the capital cost $(c)$.

$$S = p + r + t + c$$

$$S = p(1 + x)^2 + r(1 + ax) + t(1 + bx) + c(1 + fx)$$  \(2\)

where $a$, $b$ and $f$ are constants within certain ranges of speeds.

$F$ remains unchanged.

The profit per spindle $P_h$ at higher spindle speed of $(1 + x)s$ is given by

$$P_h = (R - V - 2p - px - ra - tb - cf)$$

The increase in profit from higher spindle speed is

$$P_h - P_e = x(R - V - 2p - px - ra - tb - cf)$$  \(3\)

An increase in spindle speed will lead to more saving if

$$R > V + 2p + px + ra + tb + cf.$$  \(4\)

Differentiating Eq. (3), economic increase in spindle speed is given by the value of

$$x = \frac{R - V - 2p - ra - tb - cf}{2p}$$  \(5\)

For illustration, the economics of higher spindle speeds has been worked out for a mill spinning 60s count at three spindle speeds, viz. 14,000 rpm, 17,000 rpm, and 20,000 rpm, which correspond respectively to productions of 46.4 g, 56.3 g and 66.3 g per spindle per 8 hr. The following are the further assumptions made:
(1) Raw material cost has been fixed, based on normal trading conditions, at 57\% of the yarn selling price, which is taken as Rs 36.5/kg. 

(2) Ring frame power cost would be 65\% of the total and would increase as the square of the spindle speed. 

(3) Increase in spindle speed might necessitate a reduction in work assignment to 5 sides for 17,000 rpm, and to 4 sides for 20,000 rpm and would also call for increased speed wages. However, the increased production would necessitate only engaging 30\% of additional workers up to ring spinning. 

(4) Wear of components, particularly of spindles and rings, would be more rapid—a 50\% increase in speed doubling the frequency of replacement from once in every 10 years to once in 5 years. 

(5) Higher spindle speeds would require a higher working capital as well as increased fixed assets. 

(6) Administrative expenses, fixed stores and other overheads form 7\% of the sales revenue. 

The various cost figures worked out on the above basis are summarized in Table 1. 

It can be seen that the overall increase in profits from higher speeds would be Rs 65.4 per spindle per year for a 21.4\% increase in speed and Rs 123.2 per spindle per year for a 42.9\% increase in speed. Thus, as spindle speed increases there is a steady increase in the overall profit per spindle. The higher profit is attributed to the fact that the increase in speed-related costs is lower than the increase in overall savings that can accrue from higher speeds. It is significant that the rate of increase in profit shows only a drop from Rs 3.06 per spindle per year for increase in speed from 14,000 to 17,000 rpm to Rs 2.87 per spindle for increase in speed from 14,000 to 20,000 rpm. 

Only if there is no gross profit margin, an increase in spindle speed will not lead to more savings. The economics was also worked out, assuming a 6-side assignment for ring frame tenters at all the three levels of speed considered, instead of reducing the assignments to 5 and 4 sides as has been done. The following additional assumptions were made while revising the economics. 

(1) End breakage rates would proportionately increase with spindle speeds. Thus, end breaks per 100 spindles per hour would be 18 for 17,000 rpm and 21 for 20,000 rpm as against 15 for 14,000 rpm. Higher interference would accompany the increased breakage rates which in turn would lead to drop of the machine efficiency by 0.5\% for 17,000 rpm and by 2\% in the case of 20,000 rpm as compared to 14,000 rpm speed. 

(2) Tenters will be paid speed wages at the rate of 1% increase in basic wages for every increment of 200 rpm in speed. 

The profits arrived at are found to be practically the same as before at about Rs 3 per spindle per year for every 1% increase in production per spindle. The savings from higher spindle speed would progressively diminish with increase in power cost. In any given mill, an increase in spindle speed from the existing level will be economical if \( x \) is positive, i.e. 

\[
P < (R - R - ra - tb - cf), 2
\]

Substituting the values per spindle per year for \( R \), \( \bar{V} \), etc., for 60s count, \( R = Rs 1700, \bar{V} = Rs 1.114, ra = Rs 14, \bar{R} = Rs 29 \) and \( cf = Rs 100 \), we obtain: 

\[
p < Rs 222 per spindle per year.
\]

The power consumption in a ring frame in 60s carded count running at 14,000 rpm spindle speed is about 145 units. In other words, an increase in spindle speed will lead to more savings in the case considered if the unit cost does not exceed Rs 1.53. 

In the above calculation it was assumed that an increase in power tariff would bring down the profit margin. If, however, there is an increase in yarn selling price because of higher power cost, then even a higher power tariff than the above would lead to more savings. 

**Optimum Spindle Speed During Power Shortage** 

During periods of power shortages, ring-frame
productivity is considerably affected because of the necessity to stop ring frames owing to lack of power. In the long run, power cuts can be met by installing generators, and use of generators is normally economical. However, in the short run under peak power-cut situations, the captive generating capacity available in many mills could be inadequate to meet the whole shortage. In such instances, it would be advisable to reduce the spindle speeds so that all ring frames can be worked, thereby increasing the overall ring frame production. The extent to which speeds have to be reduced would depend upon the count and the quantum of power shortage.

A formula has been derived below to arrive at the optimum reduction in spindle speed which would maximize ring frame productivity:

(i) Total units of power required for running all ring frames = \( I \)

(ii) Fixed power which does not vary with production = \( f \)

(iii) Power consumed by all ring frames = \( a(1-f) \)

(iv) Power consumed by all other departments = \( (1-a)(1-f) \)

(v) Power available to run different departments at a shortage of \( c \), (expressed as a ratio) = \( (1-c-f) \)

(vi) Power required to run a proportion of \( p \) ring frames with spindle speed reduced from \( s \) to \( g \) = \( p(1-f)g^2 \)

(vii) Power required to run the other departments for the reduced spindle speed at ring spinning = \( p(1-a)(1-fg) \)

Since (vi) and (vii) should add up to (v),

\[ pag^2 + p(1-a)g - \left( \frac{1-c-f}{1-f} \right) = 0 \]...

(6)

Obviously, the quantum of production of the ring frame department is maximum, if \( pg \) is unity. Since \( g \), the reduction in speed, is to be necessarily less than unity, the maximum production is achieved when \( p = 1 \), that is, when all the ring frames are worked.

Hence, for maximum production

\[ ag^2 + (1-a)g - \left( \frac{1-c-f}{1-f} \right) = 0 \]...

(7)

The factor \( \left( \frac{1-c-f}{1-f} \right) (= k) \) is the maximum proportion of ring frames that can be worked without any reduction in spindle speed.

### Table 2—Percentage Reduction* in Spindle Speeds to Work All Ring Frames under Different Levels of Power Shortages

<table>
<thead>
<tr>
<th>Ring frame power as % of total less fixed power (( f ))</th>
<th>Average count</th>
<th>Power shortage 25%</th>
<th>Power shortage 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>10s</td>
<td>20.0</td>
<td>42.8</td>
</tr>
<tr>
<td>50</td>
<td>16s</td>
<td>18.7</td>
<td>40.6</td>
</tr>
<tr>
<td>60</td>
<td>20s</td>
<td>17.6</td>
<td>38.4</td>
</tr>
<tr>
<td>70</td>
<td>30s</td>
<td>16.6</td>
<td>36.4</td>
</tr>
<tr>
<td>80</td>
<td>60s</td>
<td>15.7</td>
<td>34.5</td>
</tr>
<tr>
<td>85</td>
<td>100s</td>
<td>15.3</td>
<td>33.6</td>
</tr>
</tbody>
</table>

*\((1-g) \times 100\), where \( g \) is obtained from Eq. (8).

Solving Eq. (7), the reduction in speed for maximum production is

\[ g = \frac{-(1-a)+(1-a)^2+4ka}{2a} \]...

(8)

By applying Eq. (8), the reduction in spindle speeds to be made to work all ring frames has been arrived at for two levels of power shortages and the values are shown in Table 2.

Table 2 shows that in a mill spinning 60s count if there is a 25% power shortage, the ring frame spindle speeds should be reduced by 15.7%, so that all the ring frames can be worked.

On the other hand, if the spindle speed is not reduced, 26.3% \( \left(=(0.25/0.95) \times 100\right) \) of ring frames will have to be stopped under a power cut of 25%. Thus, as against a 15.7% drop in production from reduced speeds, there would be a fall in production to the extent of 26.3% because of stopping the ring frames.

### Acknowledgement

The author is thankful to Shri R. Rajamanickam for his help in working out the economics of the higher spindle speeds in ring frames.

### References

