CHAPTER 5

DESIGN ANALYSIS AND OPTIMIZATION FOR
PRODUCTIVITY OF SPINDLES

5.1  INTRODUCTION

Productivity is the talk of the day and increase in production is
looked upon as the key to prosperity at all levels. Productivity refers to the
relationship between the result and the means employed, or to be more
specific, between the product and the factors used for obtaining it. It seeks to
measure the economic soundness of the use of the means. Consequently,
productivity can be considered to be higher when maximum output is
obtained at the minimum expense of the resources. Precisely, productivity is
the balance between all the factors of production that will give the greatest
output for the smallest effort.

To reduce the above description of productivity to technical terms, it
is the ratio of output (of product) to the input (of factors required for
producing the product). The output may be measured in terms of the units of
goods produced or the value of the goods and services produced. The input,
on the other hand refers to the combination of the raw materials, machinery,
worker’s time, power, efforts and the imagination of the entrepreneur and the
managers.
5.2 PRODUCTION AND PRODUCTIVITY

The term production should be clearly distinguished from productivity. Production refers to the volume, value or quality of goods and services produced in a given period by a worker, plant or firm. It is the sum of the results achieved by the various factors used together. Productivity, on the other hand is concerned not merely the total value or volume of the output or production. What is more important, it shows the efficiency of production. In other words, productivity is relative to the resources used in turning out a certain amount of physical output, while production is used in more or less absolute sense. The distinction between the two becomes all the clear when we find that all the increase in production do not necessarily result in an increased productivity.

5.3 MEASURES OF PRODUCTIVITY

Productivity of labour is measured and expressed in two ways:

1. Labor cost per unit of output; and
2. Output per man-hour

5.3.1 Factors Affecting Productivity

1. Technological development; and
2. Employee’s performance.

5.4 EFFICIENCY, ECONOMY AND PRODUCTIVITY

There are two broad ways of improving upon productivity at any point of time.
1. Attempts can be made to increase output with the same amount of input;

2. Efforts may be made to reduce the input for the existing level of output.

When higher productivity is the outcome of better utilization of resources, it is referred to as an increase in efficiency. On other hand, when saving and conservation of resources result in higher productivity, it is described as economy. Economy and efficiency are two routes merging together at the goal of increased productivity.

A study on textile spindles is elaborated here, in which, by trying out different processes and machines, the productivity is increased. A copying lathe is the normal procedure for the manufacture of the spindle blades and the aluminum plugs in the spindle assembly used in textile frames. But, by trying them out using a single spindle automate is analyzed initially. Then, using a swaging process in a swaging machine set-up made for the trials is also analyzed. It is found that by swaging not only is there an increase in production but also there is a saving in the material and labour along with an increase in the tensile strength. Presented here, is the design analysis and statistical data comparison for the various processes that have been tried out for the manufacture of spindle blades and aluminum plugs of the textile spindles.

5.5 DESIGN ANALYSIS

Textile spinning frames are having 440 spindle assemblies each. A spindle assembly consists of spindle blade made up of En31 steel, aluminum plug made up of LM4 aluminum and wharve made up of cast iron Fe 200 material and assembled together as shown in Figure 5.1.
5.5.1 Machining Process

The following machining processes of spindle blade, aluminum plug and wharve are normally processed using a copying lathe.

**Spindle Blade**

The following are the machining process involved in the production of spindle blade:

- Facing;
- Taper turning 1;
- Taper turning 2;
- Pointing 1;
- Pointing 2;
- Cylindrical grinding 1;
- Heat treatment; and
- Cylindrical grinding 2.

**Aluminum Plug**

For the aluminum plug, the following activities are of interest to the operator:

- Facing;
- Taper turning;
- Boring;
- Drilling;
- Grinding; and
- Button fixing.

**Wharve**

Wharve has the following activities:

- Facing;
- Turning 1; and
- Turning 2.
In our study, the following machining processes of spindle blade and aluminum plug are only taken up for analysis and optimization since wharve is made up of cast iron which is brittle and cannot be swaged.

**Spindle blade**

Spindle blade processing involves the following:

- Facing ;
- Taper turning 1;
- Taper turning 2;
- Pointing 1; and
- Pointing 2.

**Aluminum plug**

Only two operations are applicable to aluminum plug processing, namely:

- Facing; and
- Taper turning.

### 5.5.2 Analysis I

#### 5.5.2.1 Spindle blade machining

A. Regular machining on copying lathe (normal manufacturing procedure)

Each individual cut pieces are fixed to the chuck and machined.
Initial observations

The following are the initial observations recorded:

a. Raw material weight : 0.157 kg.

b. Machining time (including fixing and handling)

   Facing (both sides) : 2 minutes

   Taper turning 1 and 2 : 16 minutes

   Pointing 1 and 2 : 2 minutes

   Total : 20 minutes

B. Spindle Blade Machining on single Spindle Automate

A single Spindle Automate with change of vertical slant tooling for facing and gear box with 1:48 reduction for driving drum cam for movement of horizontal tooling for taper turning and pointing has been designed and adopted in the machining trial of Spindle Blade.

The following observations are made:

Long bar is fed, clamped and machined. Hence, machining allowance on length is getting reduced.

a. Raw material weight : 0.145 kg.

b. Machining time

   Facing and cut-off (one side) : 2 minutes

   Taper turning 1 and 2 : 14 minutes
Pointing 1 and 2 : 2 minutes

Total : 18 minutes

C. Spindle blade taper forming and pointing by swaging process.

Swaging process is similar to cold forging. Swaging setup is designed with swaging rollers fixed in an eccentric housing and internally synchronized with gears, as shown in Figure 6.2 and Figure 6.3. During rotation of the housing, swaging rollers hit against the job and material deformation takes place. Taper is formed with elongation of material. Hence a shorter length of En31 raw material is enough, which leads to a saving in materials. Thereby machining time is also reduced. Pointing is also formed by swaging.

Figure 5.2 Swaging block
Observation

a. Raw material weight : 0.105 kg.

b. Machining time
   Facing (both sides) : 2 minutes
   Taper 1 and 2 by swaging : 13 minutes
   Pointing 1 and 2 : 2 minutes
   Total : 17 minutes

5.5.3 Analysis II

5.5.3.1 Aluminum plug machining

A. Regular machining on copying lathe – Normal production process
   Individual cut pieces are machined.
Observation

a. Raw material : 0.200 kg.

b. Machining Time (including fixing and handling)
   Facing (both sides) : 2 minutes
   Taper turning : 2.5 minutes
   Total : 4.5 minutes

B. Aluminum plug machining on single spindle automate.

With a change of tooling and drum cam, facing and taper turning are carried out by feeding aluminum long bar to have a reduction in material allowance during facing. Fixing and handling time is also getting reduced.

Observation:

a. Raw material : 0.185 kg.

b. Machining time (including fixing and handling)
   Facing and Cut-off (One side) : 1.75 minutes
   Taper turning : 2.5 minutes
   Total : 4.25 minutes

C. Aluminum plug swaging process

By swaging process, required taper and length is formed by deformation and elongation of LM4 material. Due to elongation, a shorter length of raw material is taken.
Observation

a. Raw material : 0.150 kg.

b. Machining time

   Facing (both sides) : 2 minutes

   Taper by swaging : 2 minutes

   Total : 4 minutes

5.6 DISCUSSION ON PRODUCTIVITY OPTIMIZATION

5.6.1 Spindle Blade

In the case of spindle blade, saving on material is 0.012 kg and 0.052 kg respectively, for machining on single spindle automate and swaging process when compared to the normal machining on copying lathe.

In the same way, saving on machining time is 2.0 minutes and 3.0 minutes respectively, for single spindle automate and swaging process in comparison with the normal machining on copying lathe.

5.6.2 Aluminum plug

In the case of Aluminum plug, saving on material is 0.015 kg and 0.050 kg respectively, for machining on single spindle automate and swaging process when compared to normal machining on copying lathe.

Similarly, saving on machining time is 0.25 minute and 0.5 minute, respectively, for machining on Single Spindle automate and Swaging process compared to machining on copying lathe.
5.7 PRODUCTIVITY

5.7.1 Productivity of Material Comparison

Table 5.1 Productivity of material

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Component</th>
<th>Process</th>
<th>Material Weight Kg</th>
<th>Productivity increase %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Spindle blade – En 31</td>
<td>A. Machining – Copying lathe</td>
<td>0.157</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Machining – Single spindle automate</td>
<td>0.145</td>
<td>7.64</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C. Swaging - Swaging setup</td>
<td>0.105</td>
<td>33.12</td>
</tr>
<tr>
<td>2.</td>
<td>Aluminium plug- LM 4</td>
<td>A. Machining – Copying lathe</td>
<td>0.200</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Machining – Single spindle automate</td>
<td>0.185</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C. Swaging - Swaging setup</td>
<td>0.150</td>
<td>25.0</td>
</tr>
</tbody>
</table>

5.7.2 Productivity of Machine Comparison

Table 5.2 Productivity of machine

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Component</th>
<th>Process</th>
<th>Machining time (minutes)</th>
<th>Productivity increase %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Spindle Blade – En 31</td>
<td>A. Machining – Copying Lathe</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Machining – Single Spindle Automate</td>
<td>18</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C. Swaging - Swaging set up</td>
<td>17</td>
<td>10.0</td>
</tr>
<tr>
<td>2.</td>
<td>Aluminium Plug- LM 4</td>
<td>A. Machining – Copying Lathe</td>
<td>4.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Machining – Single Spindle Automate</td>
<td>4.25</td>
<td>5.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C. Swaging - Swaging set up</td>
<td>4.0</td>
<td>11.11</td>
</tr>
</tbody>
</table>
From the above discussion, it is very much evident that Swaging process gives a better saving on material for both Spindle Blade and Aluminium Plug leading to a productivity increase of 33.12% and 25.0% respectively. On machining time also a substantial saving is noticed for both the components which give rise to a productivity increase of 10.0% and 11.11% respectively as depicted in the bar charts of figure 5.4 and 5.5. Cost benefit and total productivity improvement are compared for both the components in Table 5.3.

![Figure 5.4 Material productivity](image)

Figure 5.4 Material productivity

![Figure 5.5 Machine productivity](image)

Figure 5.5 Machine productivity
1B - Spindle blade machining on single spindle automate

1C - Swaging of spindle blade

2B - Aluminum plug machining on single spindle automate

2c - Swaging of aluminum plug

Table 5.3 Cost reduction and productivity improvement

<table>
<thead>
<tr>
<th>Component</th>
<th>Machine /Process</th>
<th>Copying lathe/ machining</th>
<th>Single spindle automate/machining</th>
<th>Swaging</th>
<th>Cost reduction</th>
<th>Productivity improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Spindle blade</strong> - En 31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Raw material weight</td>
<td></td>
<td>0.157 kg</td>
<td>0.145 kg</td>
<td>0.105 kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2 Machining time</td>
<td></td>
<td>20.0 minutes</td>
<td>18.0 minutes</td>
<td>17.0 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3 Material cost</td>
<td></td>
<td>Rs. 11.00</td>
<td>Rs. 10.15</td>
<td>Rs. 7.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4 Machining cost</td>
<td></td>
<td>Rs. 83.33</td>
<td>Rs. 60.00</td>
<td>Rs. 51.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cost</td>
<td></td>
<td>Rs. 94.33</td>
<td>Rs. 70.15</td>
<td>Rs. 58.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cost reduction</strong></td>
<td></td>
<td>-</td>
<td><strong>Rs. 24.18</strong></td>
<td><strong>Rs. 35.98</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Productivity improvement</strong></td>
<td></td>
<td></td>
<td><strong>25.33 %</strong></td>
<td><strong>38.14 %</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. <strong>Aluminum plug</strong> – LM 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Raw material weight</td>
<td></td>
<td>0.200 kg</td>
<td>0.185 kg</td>
<td>0.150 kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2 Machining time</td>
<td></td>
<td>4.5 minutes</td>
<td>4.25 minutes</td>
<td>4.0 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3 Material cost</td>
<td></td>
<td>Rs. 44.00</td>
<td>Rs. 40.70</td>
<td>Rs. 33.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4 Machining cost</td>
<td></td>
<td>Rs. 18.75</td>
<td>Rs. 14.17</td>
<td>Rs. 12.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cost</td>
<td></td>
<td>Rs. 62.75</td>
<td>Rs. 54.87</td>
<td>Rs. 45.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cost reduction</strong></td>
<td></td>
<td>-</td>
<td><strong>Rs. 7.88</strong></td>
<td><strong>Rs. 17.75</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Productivity improvement</strong></td>
<td></td>
<td></td>
<td><strong>12.56 %</strong></td>
<td><strong>28.29 %</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conversion rate: Rs.1 = US dollar 0.016
Further study can be made on the swaging setup to improve it for the enhancement of productivity on other machining components also. It is noticed as a consequence of the swaging process that the tensile strength of spindles increased from 850 N/mm\(^2\) to 1400 N/mm\(^2\). This phenomenon increases the life of the spindles.

5.8 CONCLUSION

Swaging process when compared to conventional machining processes is a sustainable and eco-friendly industrial process. Not only productivity on cost is noticed to improve up to 38.14%, but also, there is an increase in life performance.

Higher productivity is of vital importance for the speedy industrialization and economic development. The available resources have to be used in such a manner that both the total output and the productivity per unit are increased. In this manner, capital will become available for investment in new plants and projects opening the way to economic advancement.

In short, improvement in productivity of textile spindles brings the following advantages to the firm and the community at large.

1. Reduction in the cost of raw materials (through increase in the productivity of raw materials);
2. Reduction in labor cost per unit of output;
3. Reduction in overheads and power cost per unit of output;
4. Reduction in the price of goods;
5. Increase in wages and salaries (through schemes for sharing the gains of productivity around 10%);

6. Increase in the reserve fund around 35 lakhs that can be utilized for sharing the gains of productivity;

7. Better standard of living for people through increase in their income and improvement in the quality of goods that can be made available at cheaper prices; and

8. Increase in the competitive strength in export market through reduction in cost of production and improvement in the quality of output.