ABSTRACT
This paper discusses the case study and comparison of productivity of component using conventional horizontal milling machine and special purpose gang milling machine (SPM) for manufacturing of conveyor chain bushes. In this case study, the SPM is used for manufacturing of conveyor chain bushes which requires two flat milling operations at both ends. In this paper the following studies are carried out 1. Reduction in cycle time due to automation, 2. Increase in productivity both qualitative and quantitative, 3. Less human intervention, indirectly reduction in operator fatigue, 4. Less rejection due to automatic controls and 5. Increase the profit of company.

1. INTRODUCTION
Production quality and low production cost are essential for the success of manufacturers in today's competitive market. SPMs are very useful for producing large quantities of high quality products at low costs. These machines can also be altered to produce similar components when necessary. High accuracy, uniform quality, and large production quantities are important characteristics of SPMs. The component for which SPM designed and developed is bush for chain conveyors. These chain conveyors are used in sugar industries and other process industries for material handling purposes. Dimensions of bush vary according to design of conveyors but basic geometry of all bushes remains same. Figure 1 shows the Basic geometry of bush. Four milling operations (two at both ends which are diametrically opposite to each other) are required to be carried out on work piece to manufacture bush.

Figure 1: Basic geometry of bush

In earlier process of manufacturing the bushes were machined by using conventional horizontal milling machine with appropriate fixture. By using conventional process only two side milling operations were performed on each bush at a time and all job setting and machining activities carried out manually. To rectify these drawbacks new SPM is designed and developed by following USA approach of automation and process improvement. According to this approach existing manufacturing process is understood, simplified and automated. New concept of automation is developed with focus on specialization of operation, simultaneous operation and increased flexibility strategies of automation.

2. SETUP DETAILS
The new developed machine consists of use gang milling system. Four side milling operations which require two setups for each job should possible to manufacture in a single setup. Machine includes automatic clamping, de-clamping and feed providing system. Machine is capable to manufacture all types of bushes with minor changes in tool setting and fixture setup. Design calculations of machine parts are made by following engineering principles and technical information. Parts are designed to meet functional requirements and also DFM and DFMA principles keeping in mind. The final outcome of the design process consists of description of machine in the form of drawings of assemblies and individual components. Various two-dimensional (2-D) and three dimensional (3-D) geometric drawings are prepared by using Solid Works CAD software.

2.1 Mechanism of SPM
Mechanism of new developed special purpose machine consists of--

1. Two vertical spindle milling heads with two cutters on each for performing four side milling operations simultaneously in single setup.
2. Lead screw mechanism for providing feed to milling head column.
3. Hydraulic mechanism for providing automatic feed to work table and for automatic clamping and de-clamping of work holding fixture.
4. Mechatronic means for controlling and synchronizing various hydraulic cycles, limit switches signal system and manufacturing operations.

Three dimensional view of SPM prepared in Solid Works CAD software is shown in Figure 2 with number assigned to subassemblies as per table number1.
2.2 Headstock assembly

Exploded three dimensional view of headstock assembly is shown figure 3. This assembly is designed to rotate the milling cutters and hence providing cutting force for performing milling operation on work piece.

**Figure 3: Headstock assembly**

Assembly consists of cast iron head stock housing with honing bore for interference fitment of cup of taper roller bearings. Main part of this subassembly is spindle made from case hardened EN 353 material. This spindle is secured in headstock housing by using two taper roller bearings in back to back arrangement. Bearing selection is done by following standard bearing selection procedure and referring SKF bearing selection catalogue. Diameter of spindle is calculated by following standard shaft design process and checked by static structural analysis using finite element software - Ansys. Bearing sizes are provided at two positions on spindle by cylindrical grinding process. Spindle consists of ISO 40 taper grinded hole for securing arbor. Arbor is also made from case hardened EN 353 material with taper portion at one end. At one end of arbor tapping is provided so it can lock in spindle taper hole by screwing draw bar from one end of subassembly. Arbor is positively locked to spindle by fitting square pins in two slots provided at front ends of spindle and arbor. Key way is provided on arbor for mounting milling cutters. Distance between cutters is adjusted by placing cutter spacer of suitable length between cutters according to dimensions of work piece to be machined and locked in position by tightening chuck nuts and lock washer. Timing belt pulley is push fitted and keyed to spindle. Front fixed cap is fitted to headstock housing. Front rotary cap inserted in front fixed cap. Rear cap 2 is fitted to headstock housing. Rear cap 1 is fitted to Rear cap 2. Bearings are preloaded by bearing chuck nuts and locked in position by lock washer. Drive to timing pulley is provided by three horse power squirrel cage induction motor through timing belt. Design and selection of timing belt and timing pulley is done by referring GATES rubber company catalogue. Design and selection of electric motor is done by following engineering principles, mathematic calculations and referring manufactures catalogue published by Hindustan Electrical Motors.

**Table 1: Subassemblies numbering**

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Slide Assembly</td>
</tr>
<tr>
<td>2,8</td>
<td>Dovetail Slide Assembly</td>
</tr>
<tr>
<td>3,7</td>
<td>Headstock Assembly</td>
</tr>
<tr>
<td>4</td>
<td>Column</td>
</tr>
<tr>
<td>5</td>
<td>Machine Bed</td>
</tr>
<tr>
<td>6</td>
<td>Fixture Assembly</td>
</tr>
</tbody>
</table>

2.3 Dovetail slide assembly

Exploded three dimensional view of dovetail slide assembly is shown in figure 4. This assembly is designed to provide depth of cut while performing milling operation. Lead screw mechanism is used to convert rotary motion in to linear motion.

**Figure 4: Dovetail slide assembly**

Assembly consists of cast iron bottom slide on which top dovetail slide is mounted. Mating faces of bottom slide and top dovetail slide are grinded and scraped so that there should be smooth relative motion in between them. Dimensional limits and geometrical tolerances are provided such that both slides should align properly and to achieve accurate movement of top dovetail slide while working of assembly. Parallel wedge is placed in between two slides to adjust clearance between them. Lead screw is square threaded and secured in position by fitting in bearing block assemblies at both ends. Ball bearing bracket is provided at one end of lead screw to fit ball bearings to take radial load. At other end thrust bearing assembly is provided to fit thrust bearings and to take thrust load. Brass bush is placed between two thrust bearings so that there should be minimum wear of lead screw as brass is possessing good bearing property. Lead screw is assembled with top dovetail slide by using dovetail slide lead screw nut which is also made up of brass metal. Hand wheel is keyed to lead screw end.

When hand wheel is rotated there is rotary motion of lead screw. This rotary motion is converted into linear motion of top dovetail slide by means of lead screw nut. As head stock assembly is fitted on column which is fitted on top dovetail slide; linear movement of top dovetail slide provides depth of cut for performing milling operation on work piece when hand wheel is rotated.

2.4 Slide assembly

Exploded three dimensional view of slide assembly is shown in figure 5. This assembly is designed to provide feed while performing milling operation. Hydraulic power is used for movement of slide.

**Figure 5: Slide assembly**
This assembly consists of cast iron base slide with grinded faces on which two slide strips are fitted. Slide strips are made up of through harden EN 31 material. On slide strips cast iron top slide is mounted. Mating faces of top slide with slide strips are grinded and scraped so that there should be smooth relative motion in between them. Dimensional limits and geometrical tolerances are provided to top slide such that it should align properly and to achieve accurate movement of top slide while working of assembly. Keeper plates are fitted to top slide to lock it in position. Wedge is placed in between base slide and top slide. This wedge can be adjusted by using wedge lock plate and M 8 stud nut to set clearance between slide strips and top slide. Cylinder bracket is fitted to one side of base slide to mount hydraulic cylinder. Rod of this hydraulic cylinder is locked with top slide by means of rod bracket.

Work piece holding fixture is mounted on slide assembly. When there is longitudinal movement of top slide by means of hydraulic cylinder; work piece passes the rotating cutters and hence milling operation is performed. Stroke of this slide can be adjusted by means of limit switch and trip dogs. Trip rail is fitted to top slide and three trip dogs are mounted on it. One trip dog is for detecting home position of slide and other two trip dogs are for detecting two extreme limit positions of slide. Limit switch give signals to direction control solenoid valve of hydraulic system and hence direction and stroke of slide is adjusted as per requirement. Control and synchronization of hydraulic cylinder is achieved by configuring it in PLC program.

2.5 Fixture assembly
Exploded three dimensional view of fixture assembly is shown in figure 6. This assembly is designed to hold the work piece rigidly by use of hydraulic power while performing milling operation.

![Figure 6: Fixture assembly](image)

This assembly is designed to hold the work piece rigidly by use of hydraulic power while performing milling operation.

Work piece to be machined is held on V block and clamped rigidly in position by clamp force. To machine work piece accurately it should not move while machining; for the same reason hydraulic power is used. Control and synchronization of hydraulic cylinder is achieved by configuring it in PLC program.

3. MANUFACTURING
All parts of the machine are manufactured as per drawing specifications. Each dimension mentioned on drawing has its own importance. It is mandatory to manufacture each part as per drawing to meet functional requirement for which that part has designed. Every part of each subassembly is checked against its drawing and quality sheets are filled accordingly. After availability of all parts subassemblies are prepared. Main assembly of machine is done with following geometrical checks to achieve machining accuracy.

3.1 Geometrical checks of machine
1. Arbors of both headstock assemblies must be parallel to each other and coplanar.
Check – Take dial gauge and dial stand assembly. Place dial stand on one arbor and set dial gauge pointer to other arbor. Move dial stand up and down on arbor and observe reading of dial gauge; permissible misalignment is up to 0.01 mm.
2. Both dovetail slides must move in-line to each other.
Check – Take dial gauge and dial stand assembly. Place dial stand on front grinded face of one bottom dovetail slide and set dial gauge pointer on the grinded face of other bottom dovetail slide. Move dial stand and observe reading of dial gauge; permissible misalignment is up to 0.01 mm. At the same time center line of both bottom dovetail slides must be in-line.
3. Slide assembly must move perpendicular to both dovetail slides.
Check – Take dial gauge and dial stand assembly.
Place dial stand on front grinded face of one bottom dovetail slide and set dial gauge pointer on face of slide strip of slide assembly. Move dial stand and observe reading of dial gauge; permissible misalignment is up to 0.01 mm. Repeat the same procedure by pacing dial stand on grinded face of other bottom dovetail slide.

After final assembly of total machine doweling is done at all appropriate locations so that respective parts will secure at their proper positions and final alignment of machine will not get disturbed by vibrations and other factors responsible for misalignment of machine. This doweling is also helpful while maintenance of machine. When machine is disengaged for maintenance and after performing maintenance parts can be fitted at their original positions by referring doweling locations.

4. CASE STUDIES
After performance trails following observations are noted -

4.1 Reduction in cycle time
By using conventional method cycle time required to manufacture single bush is 57 seconds where as cycle time required to manufacture single bush with SPM is 27 seconds. Hence cycle time is reduced by 30 seconds.
4.2 Quantitative productivity improvement
After studying production data it is observed that number of bushes produced per shift using conventional manufacturing method are 347 numbers and by using SPM 866 numbers. Hence increase in production per shift by 519 numbers of jobs. Hence production rate improvement by 2.5 times is achieved.

4.3 Improved repeatability and accuracy
Intensive care in design and manufacturing of machine to achieve highest machining quality of bushes to be produced on machine, results in improved repeatability and accuracy in bush production. In conventional method bush was manufactured in two setups; hence quality problems were arise due to uneven conditions of two setups. On new developed machine all four flat milling operations are performed in a single setup which resolved the problem due to setup change. In standard manufacturing conditions 96 % accuracy is achieved.

4.4 Less human intervention
Drastic reduction in work load is attained through the automation process which directly helps in less operator fatigue. This reduces labor cost. Daily wages of machine operator is considered 600 rupees. Then labor cost for production of each job by conventional manufacturing method is 1.73 Rs/job and by using SPM = 0.69 Rs/job. Hence labor cost is reduced by 1.04 Rs/job. As machine is completely automated it can be operated by semiskilled labor having less daily wages and hence it is possible to achieve again more reduction in labor cost. Skilled operator is required only for machine setting. This also solves problem of shortage of skilled labor. Less human intervention also contributed in workers safety.

4.5 Economic justification of SPM
Economical Investment in automation can be justified as shown in table 2.

Table 2: Economic justification of SPM

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Horizontal milling machine</th>
<th>SPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savings in labor cost per job (Rs.)</td>
<td>1.04</td>
<td></td>
</tr>
<tr>
<td>Total machine manufacturing cost (Rs.)</td>
<td>841,705</td>
<td></td>
</tr>
<tr>
<td>Numbers Jobs required to produce for amortization of machine cost</td>
<td>80,933</td>
<td></td>
</tr>
<tr>
<td>Numbers jobs produced per shift using machine</td>
<td>866</td>
<td></td>
</tr>
<tr>
<td>Numbers Shifts required producing 8,093,311 numbers of job</td>
<td>934</td>
<td></td>
</tr>
<tr>
<td>If machine runs in two shifts daily; number of days required</td>
<td>467</td>
<td></td>
</tr>
<tr>
<td>Number of months required by considering 25 days per month</td>
<td>18.67</td>
<td></td>
</tr>
<tr>
<td>By considering interest rate and other costs total payback period of machine in months</td>
<td>22</td>
<td></td>
</tr>
</tbody>
</table>

4.6 Less rejection due to automatic controls
Because of high accuracy and repeatability achieved due to automatic control system, rejection of bushes is reduced. This results in qualitative productivity improvement. In conventional method all job setting and machining activities were performed manually. Hence production quality was majorly dependent on operator’s skill and efforts. In new method of machining all job setting and machining activities are performed by automatic controls which results in greater uniformity and conformity to quality specifications. Once machine is stetted properly, operator contribution is limited to only loading and unloading of job. Thus an automatic control is main reason for quality improvement and less rejection.

5. Conclusion
An effort is taken to design and develop a special purpose gang milling machine for manufacturing of conveyor chain bushes. Existing manufacturing process is understood, simplified and automated. New concept of automation is developed with focus on specialization of operation, simultaneous operation and increased flexibility strategies of automation. Parts are designed to meet functional requirements and also DFM and DFMA principles keeping in mind. Various two-dimensional and three dimensional geometric drawings are prepared using Solid Works CAD software. After completion of parts and subassemblies manufacturing machine is assembled and working trails of are conducted for performance analysis. Considerable improvement in productivity both qualitative and quantitative is observed with all other benefits of automation. It is concluded that new developed special purpose machine is technically and economically justified and proven its effectiveness over conventional manufacturing process.

REFERENCES


