Loading and Unloading System Design for external Centerless Grinding Machine Using Automation

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Abstract— In the present work external centerless grinding machine, the manual feeding of work pieces can be replaced by designing and development of automatic feeding system which helps to feed the work pieces automatically into the centerless grinding machine. After grinding of the work piece automatic unloading can be done and finally collected in the tray. All the parts and assembly modeling of automatic loading and unloading system using CATIA V5R19. The cycle time analysis result shows to find the number of work pieces grind per minute and also show how the process takes place with respect to the time.

Key words: Grinding Machine, CATIA V5R19

I. INTRODUCTION

Center less grinding is a process for continuously grinding cylindrical surfaces in which the work piece is supported not by centers or chucks but by a rest blade. The work piece is ground between two wheels. The larger grinding wheel does grinding, while the smaller regulating wheel, which is tilted at an angle, regulates the velocity of the axial movement of the work piece. Center less grinding can also be external or internal, traverse feed or plunge grinding. The most common type of center less grinding is the external traverse feed grinding.

II. LITERATURE REVIEW

Three Dimensional grinding Model is described by analytical methods. The model includes a parametrical description of all grinding gap elements and their kinematics and enables the determination of optimal regulating wheel form. Moreover, the model can be used in a simulation tool that creates an interactive virtual environment, places all grinding gap elements in the defined set-up and visualizes the process[1].

Thermal variation in machine tools greatly affects the dimensional tolerances of work pieces and causes various defects in manufacturing process. For preventing thermal distortion that makes to substantial improvement in quality, manufacturing efficiency and energy saving[2].

During operation there is chance of overlapping of rods that damages the grinding wheel or stops the operation, for that purpose pneumatic proximity sensor is attached. Output of sensor placed nearer to the grinding machine, input attached to the cylinder. Mainly pneumatic proximity sensors involve the use of compressed air, displacement or the proximity of an object being transformed into a change in air pressure. Low pressure air is allowed to escape through a port in front of the sensor. This escaping air, in the absence of any close-by object, escapes and in doing so also reduces the pressure in the nearby sensor output port. However, if there is close-by object, the air cannot so readily escape and result is that the pressure increase in the sensor output port. The output pressure from the sensor thus depends on the proximity of objects. Here, in this case inductive proximity sensor is used. It can be used for the detection of metal objects and is best with ferrous metals [3].

III. DEVELOPMENT OF THE MECHANISM

For automatic loading and unloading of components from the centerless grinding machine mainly requires the mechanism. The mechanism mainly consist of inclined plate for placing of the rods, pneumatic cylinder for lifting of rods and belt drive for transporting of rods up to the work rest blade. Developed mechanism as shown in Fig. 1.

The modeling tool CATIA V5R19 used for parts and the assembly modeling of centerless grinding automation. The features of the CATIA V5R19 are, CATIA V5R19, Developed by Dassault systems, is a completely re-engineered, next-generation family of CAD/CAM/CAE software solutions for product lifecycle management. Through its exceptionally easy-to-use state of the art user interface, CATIA V5R19 delivers innovative technologies for maximum productivity and creativity, from concept to the final product. It reduces the learning curve, as it allows the flexibility of using feature based and parametric designs.

CATIA V5R19 serves the basic design tasks by providing different workbenches. A workbench is defined as a specified environment consisting of a set of tools, which allows the user to perform specific design tasks in a particular area. The basic workbenches in CATIA V5R19 are Part Design workbench, Wireframe and Surface Design workbench, Assembly Design workbench and Drafting workbench.

Fig. 1: Three-dimensional representation of developed mechanism for centerless grinding machine.
A. Inclined Plate for Placing Rods:
Inclined plate which is mounted over the table with support of extrusion, initially rods are stacked over the surface of the plate and between two bar spaces. The plate which is slightly inclined for the purpose of rolling these stacked bars. At the front side of the plate there is space for the movement of L-plate which is attached to the through piston cylinder (double acting). L-plate that lifts the rods one by one up to the top surface of sheet metal and roll the rod on this sheet, finally fall over the rotating belt drive.

B. Double acting pneumatic cylinder:
Through piston (double acting) cylinder is used to lift the rod, piston rod is connected to the L-plate. Cylinder is mounted at one face of the taper plate using linear-motion guide and guide rod arrangements. Only 60mm stroke is required to lift the rod up to the top surface of the sheet metal and after that rod rolls over the surface of sheet metal and finally rod fall on the moving belt.

C. Belt drive:
Usually belt drives are three types flat, v-belt and circular belt or rope drives. Circular belt drive or rope drive is used for the rods moving towards the grinding machine, on either side of the rope two long bars provided for the purpose of guiding the rods. While other two belt drives (flat and v-belt) are not chosen because of rod that rolls over the belt and not properly guided towards the grinding machine. The rope drive is usually made up of rubber material.

Two pulleys are used to rotate the rope drive which held by the extrusion using holders. At one end of driver pulley there is motor plate for mounting the motor. The rope drive is rotated using induction motor (90 W). There is chain transmission between the pulley and motor for rotating rope drive.

D. Motor selection procedure:
Required procedure
First, determine the basic required specification such as operating speed, load torque, power supply voltage and frequency.
Calculating operating speed
Induction and reversible motor speed can’t be adjusted. Motor speed must be reduced with gear heads to match the required machine speed. It is therefore necessary to determine the correct gear ratio.
Calculate the required torque.
Select the motor and gear head.

E. Design calculations:
Selection of motor
Total mass of work and tension of belt, \( m_1 \)
Tension of belt, \( T = 40 \) kg
Total mass of work, \( M = 7 \) kg (assumed)
Total mass of work and tension of belt, \( m_1 = 40+7 = 47 \) kg
Friction coefficient of sliding surface, \( \mu = 0.3 \)
Roller diameter, \( D = 88 \) mm
Mass of roller, \( m_2 = 1 \) kg
Belt roller efficiency, \( \eta = 0.9 \)
Belt speed, \( V = 387 \) mm/s
Motor power supply single phase 230 v, 50 Hz
Movement time = 8 hrs/day.

1) Determine the gear head reduction ratio
Speed at gear head out put shaft
\[
N_G = \left( \frac{V}{60} \right) \times (\pi \times D) \quad \text{……. (1.1)}
\]
\[
N_G = \left( \frac{387}{60} \right) (\pi \times 88) = 83.99 \sim 84 \text{ r/min}
\]
Because the rated speed for a 4- pole motor at 50 Hz is 1250 r/min the gear ratio is calculated.
\[
i = \left( \frac{1250}{84} \right) = 14.88 \sim 15
\]
From within this range a gear ratio \( i = 15 \) is selected.

2) Calculating the required torque on a belt conveyor, the greatest torque is needed when starting the belt, to calculate the torque needed to start up the friction coefficient of sliding surface is determined.

\[
F = \mu \times m \times g \quad \text{……. (1.2)}
\]
\[
F = 0.3 \times 47 \times 9.81 = 138.32 \text{ N}
\]
Load torque,
\[
T_L = \left( \frac{(F \times D)}{(2 \times \eta)} \right) \quad \text{……. (1.3)}
\]
\[
T_L = \left( \frac{(138.32 \times 88)}{(2 \times 0.9)} \right) = 6762.311 \text{ N-mm}
\]
\[
T_{L1} = 6.762 \text{ N-m}
\]
The load torque obtained is actually the load torque at the gear head drive shaft so this value must be converted into the load torque at the motor output shaft. If required torque at the motor output shaft is \( T_M \) then,
\[
T_M = \left( \frac{T_{L1}}{(i \times \eta)} \right) \quad \text{……. (1.4)}
\]
\[
T_M = 6762.311 \times 15 / 60 \times 0.66 = 683.06 \text{ N-mm}
\]
\[
T_M = 0.683 \text{ N-m}
\]

The suitable motor is one with starting torque 0.68 N.m. Therefore motor M91Z90G4GGA is the best choice. Since gear ratio of 15 is required, select the gear head MZ9G15B which may be connected to the M91Z90G4GGA motor.[5]

3) Since the motor selected has a rated torque of 690 N-mm, which is somewhat larger than the motor actual load torque. The motor will run at higher speed than the rated speed. Therefore the speed is used under no-load conditions [approximately 1258.32 rpm] to calculate the belt speed thus determined. Whether product selected meet the required specifications.

Motor speed, \( \omega = \frac{N_{M}}{N_1} \) \text{rpm} \quad \text{…….. (1.5)}
\[
90 = 0.683 \times \left( \frac{(2 \times \pi \times N_1)}{60} \right)
\]
\[
N_1 = 1258.32 \text{ rpm}
\]
Rated speed, power, \( P = T_{R} \times \omega \) \text{…….. (1.6)}
\[
90 = 0.69 \times \left( \frac{(2 \times \pi \times N_1)}{60} \right)
\]
\[
N_2 = 1245.56 \text{ rpm}
\]
Belt speed, \( V = (N_{M} \times \pi \times D) / (60 \times i) \) \text{…….. (1.7)}
\[
V = \left( \frac{1258.32 \times 2 \pi \times 88}{60 \times 15} \right)
\]
\[
V = 386.52 \sim 387 \text{ mm/s}
\]
The motor meets the specifications.
Using Panasonic catalog motor selection made. [5]

Selection of cylinder
Double acting cylinder (through piston) is used to lift the part. Selection of cylinder based on force, pressure and area.
Using relation
\[
P = \frac{F \times L}{A} \quad \text{…….. (1.8)}
\]
\[
Rod diameter, \( d = 5.42 \) mm
\]
\[
Rod length, \( l = 245 \text{mm}
\]
\[
Density of rod, \( \sigma = 7860 \text{ kg/m}^3
\]
\[
Mass of rod, \( m = 0.044 \text{ kg}
\]
Mass of L-plate, \( m = 0.95 \text{ kg}
\]
\[
Force, \ F'' = (\text{mass of L-plate + mass of rod}) \times 9.81
\]
\[
Force, \ F'' = (0.95 + 0.044) \times 9.81 = 9.76 \text{ N}
\]
Assumed pressure, \( p = 6 \text{ bar} \times 6 \times 10^3 \text{ N/m}^2
\]
\[
Area = (\text{force} / \text{pressure}) = (9.76 / 6 \times 10^3) = 1.627 \times 10^{-5} \text{ m}^2
\]
\[
[(\pi/4) \times d^2] = 1.627 \times 10^{-5} \text{ m}^2
\]
the difference between the first and second rod which travel down on the belt it takes 2.4 seconds. The second rod completes cycle time at 23.6 seconds. The third rod lifts after getting the signal form the sensor it takes timing to travel on the belt 11.2 seconds. This cycle repeats until to find the parts per minute.

Centrifugal tension, \( T_c = \frac{(w \times V^2)}{g} \) 14.7a[6]

\( T_c = 0.1973 \times 0.386^2 / 9.81 \)

\( T_c = 3.496 \times 10^{-3} \) Kg

Tension in tight side of rope, \( T_1 = T - T_c \)

\( T_1 = (40 - 3.496 \times 10^{-3}) = 39.997 \) Kg

Using relation

\[ 2.3 \log \left( \frac{T_1}{T} \right) = \mu \cos \theta \] 7

\[ 2.3 \log \left( \frac{T_1}{T} \right) = 0.3 \times \pi \times \cos \theta \] 22.5°

\[ 2.3 \log \left( \frac{T_1}{T} \right) = 2.46 \]

\[ \log \left( \frac{T_1}{T} \right) = (2.46 / 2.3) \]

\( T_1 / T = 11.72 \)

\( T_2 = 39.997 / 11.72 \) Kg

\( T_2 = 3.4127 \) Kg.

Material removal rate [MRR]

\[ MRR = \frac{(W_e - W_d)}{\left( \times 1 \right) \text{ m}^3 / \text{sec} \] 8

\[ MRR = \frac{0.043 - 0.043}{7870 \times 8} = 1.5883 \times 10^{-8} \text{ m}^3 / \text{sec} \] 3

F. Cycle time analysis

The cycle time analysis made first by observing process timings with help of stop watch. This analysis helps to find the number of parts grind per minute and how the process takes place with respect to time.

The cycle begins with the cylinder piston that lift the rod, for upward movement of the piston takes 1.2 sec and downward movement takes 1.2 sec. After work piece roll on the sheet metal it takes the timing of 2 sec and fall on the belt. The work piece travels on the belt and reach up to the work rest belt it takes 8 sec. In the machining process, work piece rest on the work rest blade. Rotational driving force is generated on a work piece when it is grounded by the grinding wheel. A driving force is provided due to friction from regulating wheel. The work piece rotates slowly with the surface speed of regulating wheel independent of that of grinding wheel. Machining time is around 8 seconds after machining. The unloading of the work piece between the rollers gap it takes 1.8 sec. and finally collected in the tray.

The continuous operation of the cycle work piece may over lapping at work rest blade. To avoid the overlapping of rods the proximity sensor attached at the front of the guide bar, for every two work piece pass. After the sensor senses the object and stop the piston movement to lift the rod. After grinding of these rods, the sensor allows to lift the rod.

The first rod complete the cycle time at 21.2 second, the difference between the first and second rod which travel

<table>
<thead>
<tr>
<th>Rod no.</th>
<th>Cycle time (seconds)</th>
<th>The difference in timings (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.2</td>
<td>------</td>
</tr>
<tr>
<td>2</td>
<td>23.6</td>
<td>2.4</td>
</tr>
<tr>
<td>3</td>
<td>34.8</td>
<td>11.2</td>
</tr>
<tr>
<td>4</td>
<td>37.2</td>
<td>2.4</td>
</tr>
<tr>
<td>5</td>
<td>48.4</td>
<td>11.2</td>
</tr>
<tr>
<td>6</td>
<td>50.8</td>
<td>2.4</td>
</tr>
<tr>
<td>7</td>
<td>62.0</td>
<td>11.2</td>
</tr>
</tbody>
</table>

Table 1: Timing Difference

Total 6 parts produced in one minute. To find the production rate for one hour Production rate = 6x 60 = 360 parts/hour.

IV. CONCLUSIONS

In the present work centerless grinding machine has been automated. Automatic loading and unloading of centerless grinding machine system is designed as per drawings.

An automatic loading and unloading of centerless grinding machine has resulted into the following conclusions. By automating the centerless grinding machine reduced the labor cost i.e two operators were required for this grinding machine. One operator at loading of rods and another operator at unloading side.

Increase in the production rate around 360 parts/hour.

Reduction in the manufacturing lead time. Automation helps to reduce the elapsed time between customer order and product delivery, providing a competitive advantage to the manufacturer for future orders. By reducing manufacturing lead time, the manufacturer also reduces work-in-process inventory.

REFERENCES