ESTIMATION OF CONDITIONS IN EXCHANGEABLE JAWS DESIGN OF PNEUMATICS GRIPPER IN MILLING MACHINE WITHIN THE MANUFACTURING – ASSEMBLING SYSTEM ICIM 3000

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Abstract: The paper deals with the design of exchangeable jaws on pneumatics gripper on the CNC milling machine EMCO Concept MILL 105, which is part of the iCIM 3000 like as manufacturing and assembly system. The current shape and size of the exchangeable jaws is not suitable for the new component base. When designing exchangeable jaws to allow firm and safe clamping of rotating and non-rotating parts, it was based on limiting factors such as parameters of the pneumatics gripper, dimensions, shape and material of the clamped parts and the like.

Keywords: MILLING, NEW COMPONENT BASE, CHANGEABLE JAWS, PNEUMATICS GRIPPER, DIMENSION, ROTATING

1. Introduction

In the complete design of the preparation takes into account several requirements such as technological operation, shape and dimensions of the component, material of the components, splinters. There are also clamps with exchangeable parts such as pneumatic gripper, where only exchangeable jaws are designed.

The EMCO Concept MILL 105 CNC milling machine, which is part of the iCIM 3000 production and assembly system, is a pneumatic gripper from GRESSEL Ecopos with exchangeable jaws. The paper deals with the individual steps of designing the exchangeable jaws for a new component base.

2. Current state in the milling machine

At present, the EMCO Concept MILL 105 CNC milling machine machining of rotating parts with diameter ø 30mm and ø 40mm.

These rotating parts are clamped in clamping jaws, which also serve to clamp a plate-shaped component with dimension 80x150x14.8mm (Fig.1). All machined parts are made of aluminium. Exchangeable jaws are clamped on a pneumatic spindle with a maximum clamping length of 70mm and a jaw width of 72mm. This size is also adjustable for jaws.

3. New component base

The milling machine is designed to produce rotating components with a diameter of 32-35mm and a non-rotating components with dimensions 60x140x14.8mm (Fig.2). New rotary parts and plates are also made of aluminium.

4. Design of exchangeable jaws in the pneumatics gripper

For the new component base, exchangeable jaws are designed to allow firm and secure clamping of rotating and non-rotating components. At the same time, the jaws of the pneumatic gripper cannot clamp the new parts because their dimensions and shapes are different. The clamping of the rotating parts will be up to 8mm in height, which ensures a firm and reliable clamping at a total height of 35mm. The insufficient maximum clamping length of the pneumatic gripper affects the shape of the exchangeable jaws.

When designing exchangeable jaws, the dimensions are suggested:
• of the clamping parts of the exchangeable jaws to the gripper,
• of the clamping parts of the exchangeable jaws for the base plates,
• of the prisms of the exchangeable jaws.

4.1 Dimensions design of fixture parts of exchangeable jaws to the gripper

The clamping parts of the exchangeable jaws consist of the design of two groups of dimensions. These are the diameters of the jaws
for clamping the jaws with screws and the spacing between holes for clamping the jaws through the screws (Fig. 3). These dimensions are influenced by the pneumatic sprocket.

The most important parameter that affects the dimensions L1 and L2 is the maximum clamping length of the pneumatic gripper, which is 70 mm and the clamping stroke of the pneumatic gripper, the value of which can be selected in the range of 1 to 5 mm.

The clamping stroke determines the distance that the jaws move when they are snapped and tipped. In this case, the distance of 7mm jaws (Fig. 4a) and 11mm jaws (Fig. 4b) was determined. Thus, the clamping stroke is 4mm. Dimensions L1 and L2 can be determined on the basis of the opening and clamping stroke of the pneumatic gripper. The total width of the left and right jaw represents 59mm. Based on the design, the width of the left jaw was L1 = 25mm and the width of the right jaw L2 = 34mm.

4.2 Design dimensions of fixture part of replaceable jaws for base plates

Clamping of plates 60x140x14.8 mm is high up to 5mm. The dimensions l1 and l2 are given by the length of the plate from which the distance between the closed jaws is deducted. The sum of the lengths of the clamping parts of the left and right jaws for clamping plates is 133 mm. On the basis of the design, the length of the clamping portion of the left jaw was l1 = 66.5mm and the length of the right jaw clamping length l2 = 66.5mm (Fig. 5).

The width of the left and right jaw clamps was determined to be 77mm (Fig. 6) based on the base plate width of 60mm.

4.3 Dimensions design of prisms of replaceable jaws

Prismatic jaws are designed to clamp the rotary workpieces. The angle α is 60 °, 90 ° to 120 °. Most often prisms are used with a 90 ° angle. In this case, the prism angle α = 90 ° was also selected.

The prism design (Fig. 7) was based on the diameter of the clamped work piece D and the distance h, which represents the length of the prism, in this case determines the dimension of the clamping part for clamping the plate, i.e. h = l1. The distance h is an important value for determining the H value, which represents the distance of the edge of the clamping portion of the base plate from the component axis. The H value is defined by:

$$H = h + 0.707 \times D - 0.5 \times C \ [\text{mm}]$$  \hspace{1cm} (1)

where:
- h – flexible part dimension for fixturing of base plate [mm]
- D – workpiece diameter [mm]
- C – width of prism [mm]

If the value C is not known, it can be based on the Lzc value, which represents the distance between the clamped jaws and its value is 7mm. In this case, the relation for H is determined as:

$$H = h + \frac{L_{zc}}{2} \ [\text{mm}]$$  \hspace{1cm} (2)

where:
- Lzc – dimension between closed jaws [mm]

Based on the previous relationship (1) it is possible to derive the relationship for determining the prism width C in the form:
\[ C = 2 \times (h - H + 0.707 \times D) \text{ [mm]} \]  

(3)

Dimensions SA and SB (Fig. 7) are defined by relationships:

\[ SB = \frac{D}{2} \text{ [mm]} \]  

(4)

\[ SA = \frac{SB}{\sin \frac{\alpha}{2}} \text{ [mm]} \]  

(5)

where:

\[ \alpha \] – angle of prism \([^\circ]\)

According to previous relations, the basic prism dimensions for the rotary components with diameter \(\varnothing32\text{mm}\) (Tab. 1) have been calculated. The designed replaceable prisms are shown on (Fig. 8).

**Tab. 1: Base dimensions of prism**

<table>
<thead>
<tr>
<th>Diameter of fixtured workpieces</th>
<th>(\varnothing\text{32 mm})</th>
<th>(\varnothing\text{32 mm})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha) ([^\circ])</td>
<td>90</td>
<td>70</td>
</tr>
<tr>
<td>(h) [mm]</td>
<td>66.5</td>
<td>38.3</td>
</tr>
<tr>
<td>(H) [mm]</td>
<td>70</td>
<td>16</td>
</tr>
<tr>
<td>(C) [mm]</td>
<td>22.6</td>
<td></td>
</tr>
<tr>
<td>(SB) [mm]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(SA) [mm]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 7 Base dimensions of prism (Chvála, B.)**

**Fig. 8 Replaceable jaws for workpieces \(\varnothing\text{32 mm}\)**

For each prism, the range of possible clamping diameters can be determined. \(D_{\text{min}}\) and \(D_{\text{max}}\) are designated, representing the minimum and maximum possible clamping diameters. Workpieces with a larger or smaller diameter cannot be fixtured. Workpieces with a diameter smaller than \(D_{\text{min}}\) cannot be clamped between the jaws as they touch their faces. In the case of a workpiece with a diameter greater than \(D_{\text{max}}\), there is an unstable clamping of the workpiece in the jaws. On (Fig. 9) is shown the range of possible diameters graspable in prismatic jaws.

It is important to determine the minimum and maximum diameters to maintain sufficient clamping and workpieces stability in the jaws. In the case of the jaw itself, the range of the possible clamping diameter is greater than that of the pneumatics gripper when the minimum and maximum possible clamping diameter of the jaws is limited by the maximum possible opening of the pneumatics gripper. The initial parameters for determining \(D_{\text{min}}\) and \(D_{\text{max}}\) are the prism width \(C\) and the prism angle \(\alpha\). The minimum diameter of the workpiece that can be clamped in the prism \(C\) is based on:

\[ \sin \frac{\alpha}{2} = \frac{OA}{SA} \text{ [mm]} \]  

(6)

where:

\[ OA \] – distance (see at Fig. 9)

then:

\[ OA = SA \times \sin \frac{\alpha}{2} \text{ [mm]} \]  

(7)

Of the previous relationship shows the relationship for the minimum workpiece diameter \(D_{\text{min}}\):

\[ D_{\text{min}} = 2 \times OA \text{ [mm]} \]  

(8)

When calculating the minimum workpiece diameter, the original SA value, which was determined for the \(\varnothing32\text{mm}\) diameter, should be used. From this value, the distance between the axis of the component from the edge of the jaw (in our case 3.5 mm) is read, resulting in an SA value for the minimum workpiece diameter.

The maximum workpiece diameter that can be clamped in the prism \(C\) is determined by:

\[ \sin \frac{\alpha}{2} = \frac{OB}{C} \text{ [mm]} \]  

(9)

where:

\[ OB \] – distance (see at Fig. 9)

then:

\[ OB = C \times \sin \frac{\alpha}{2} \text{ [mm]} \]  

(10)

From the previous relation is determined the relation for maximum diameter of workpiece \(D_{\text{max}}\):

\[ D_{\text{max}} = 2 \times OB \text{ [mm]} \]  

(11)

Interchangeable jaws designed for gripping workpieces \(\varnothing32\text{mm}\) are able to handle the minimum possible diameter \(\varnothing27\text{mm}\) and the maximum possible diameter \(\varnothing54\text{mm}\).

The exchangeable jaws clamped on the pneumatic gripper are limited by the distances that arise when the jaws are tipped and clamped when determining the minimum and maximum possible clamping diameter. These distances are important to take into account when calculating the limits. In this case, the distance between the jaws is 7 mm and the cutting state is 11 mm. The new rotary components are designed to be reliably clamped at the minimum jaw distance, i.e. \(D_{\text{min}}\). The determination of \(D_{\text{max}}\) is based on the formula (2), where the distance of the broken jaws 11 mm is obtained after the value \(L_{\text{zcz}}\), thus the value \(H\) is changed to 72 mm. This value is given in the following relation (12). The value \(h\), which represents the prism length, in this case determines the dimension of the clamping part for clamping the base plate, i.e. \(h = l_1\). From formula (3), the relationship is determined for the maximum workpiece diameter \(D_{\text{max}}\):

\[ D_{\text{max}} = \frac{C - h + H}{0.707} \text{ [mm]} \]  

(12)

The minimum possible clamping diameter is \(\varnothing32\text{mm}\). The maximum possible clamping diameter is \(\varnothing34.8\text{mm}\) (Fig. 10).
4.4 Selection of suitable material for removable jaws

Steel with a minimum tensile strength about 450MPa, is one of the most commonly used materials for the jaws' jaws. The chosen material was therefore the E360 (11 700) structural steel, suitable for machine parts that have higher resistance to wear and tear (Tab. 2).

<table>
<thead>
<tr>
<th>Marking according to EN STN standard</th>
<th>11 700</th>
</tr>
</thead>
<tbody>
<tr>
<td>New marking EN</td>
<td>E360</td>
</tr>
<tr>
<td>Carbon content %</td>
<td>0.65</td>
</tr>
<tr>
<td>Lower yield point R_{y} [MPa]</td>
<td>461 – 834</td>
</tr>
<tr>
<td>Tensile strength R_{t} [MPa]</td>
<td>324 – 637</td>
</tr>
<tr>
<td>Hardness HB</td>
<td>max. 290</td>
</tr>
</tbody>
</table>

5. Determining the size of the clamping force

The size of the clamping force is an important parameter for machining. The clamping force must be greater than the cutting force so that the workpiece is not displaced or vibrated. The pneumatic sprocket used has a maximum clamping force of 3000N, which means that the cutting force must be smaller.

Determining of the size of the cutting force consists of the following steps:

- Select a suitable cutting tool
- It depends on the dimensions, shape and quality of the surface of the milled surface, also from the machined material. The selected cutting tool gives the parameters necessary to determine the cutting force, that is, the diameter of the cutting tool, the number of teeth, and the geometry of the cutting tool. Determines the number of teeth in engagement.
- Determination of cutting conditions
  - For a given milling surface and the selected tool, the depth of cut, the number of shots, is determined. From catalogs or standards, it is cutting speed, rotational speed, feed to the tooth. Specify the type and method of cooling.
  - Calculation of the cross section of the fragments taken
  - For milling, it is important to determine the width and maximum thickness of the chippings to be sampled, from which the cross section of the chips is calculated.
  - Determination of cutting resistance
    - The cutting resistance is calculated for the machined material, i.e. aluminium and the maximum thickness of the chips removed.
  - Calculate the cutting force size
    - The cutting force is calculated as the product of the cross section of the chips and the cutting resistance. If there is more teeth than one, the cutting force is determined for each tooth individually. Subsequently, the individual cutting forces are added together to calculate the resulting cutting force.
  - Determination of the safety factor
    - Security factor K ensures sufficient clamping of the workpiece at any operating force. When selecting a low security factor, there may be little clamping reliability. Determination of large K can result in unnecessarily large clamping force Fu. The size of the safe clamping coefficient K is determined by adding the individual coefficients. (Chvála, B.)
  - Determining the size of the clamping force
    - The coefficient of friction f between the workpiece and the clamping surfaces of the preparation. Its value depends on the surface of the preparation and the machining of the workpiece.

The clamping forces required to clamp the rotating components and plates have been calculated. All values were below max. The clamping force which the pneumatic claw is able to clamp.

6. Conclusion

The aim was to design replaceable jaws on the GRESSEL Ecopos pneumatic gripper clamped on the EMCO Concept MILL 105 CNC milling table. Before the design, it was necessary to evaluate the current state of the jaws. Replaceable jaws ensure clamping of diameters Ø 30mm and Ø 40mm and 80x150x14.8mm (mxdxv) plates made of aluminium. The new jaws have been designed to ensure firm clamping and setting up of newly-formed rotating components with Ø 32mm diameter and a 60x140x14.8mm (mxdxv) baseplate.

The design of jaws was based on limiting factors, such as the parameters of a pneumatic gripper as a maximum and minimum cutting, maximum clamping force, maximum clamping stroke, clamping screw spacing and others. Another important design factor was also the size, shape and material of the parts. For the versatile use of the pneumatic gripper, the shape of the designed jaws has been adapted to the gripper parameter. When designing replaceable jaws, their dimensions were proposed, which were divided into three groups. These groups consist of the dimensions of the clamping parts of the replaceable jaws, the clamping part of the replaceable jaws for the base plates and the dimensions of the jaws of the replaceable jaws.

Designed jaws have calculated the minimum and maximum diameter of parts that can be safely clamped into the jaws. Also, the minimum and maximum diameter of the parts that can be clamped into the jaws on the pneumatic gripper was calculated. With the jaws clamped on the pneumatic gripper, the minimum and maximum possible clamping diameter was limited by the maximum opening of the pneumatic gripper. The chosen material was E360 structural steel (11 700). For design components and base plates, it was necessary to determine the size of the clamping force. The required size of the clamping force must be less than the maximal clamping force of the gripper. After calculating the clamping forces, it was found that all the components and base plates could be securely clamped on the pneumatic gripper.

7. References


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