

Design and Fabrication of Fixture for Internal Grinding CNC Machine

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Abstract— The work carried out was on a special purpose grinding CNC machine-Meccanodora Cimat C-661, a 3axis PCbasedCNCcontrollerhavingmaximumspeedof40,000RPM. WhentheprojecttomodifytheCIMA TC-661ID grinder CNC machine tool was proposed, the machine tool, process and modification plan were studied. The company's requirement was to grind the inner surface of the rotary sleeve valve in the ID grinder to a very high surface finish (0.5 – 0.6 Microns) and high precision, so a new ID grinder CNC was needed. As the new machine would be too expensive, the company considered modifying the existing ID grinding C-661CNC to a general-purpose ID grinding CNC, which makes itcost-effectiveandsuitableforgrindingrotarysleevevalvesand othercylindricalparts. Aspecialfixturedesignwas requiredfor holding the sleeve valve that would serve the requirement. Therefore, a collet type of fixture was designed which will self-lock the sleeve valve with the existing setup. The designed automatic clamping system with collet fixture reduced human intervention which were often prone to errors. Therefore, considering all the design aspect, the special purpose magnetic type of fixture made up ofchrome vanadium alloy spring steel 0.50%C was replaced with a collet type offixture. Thisinturn hasfoundtoreducethetotal costfornewmachine providingmaximum benefitsinterms of company and customer.

Index Terms— CNC Internal grinding (ID) machine, Fixture, Sleeve valve, Magnetic fixture, Collet fixture.

I. INTRODUCTION

Grindingmachines, usually shortenedasgrinders, aremachinetoolsusedforgrinding, whichisatype of processing that uses a grinding wheel as a cutting tool. Each abrasive particle on the surface of the grinding wheel willcutasmallfragmentfromtheworkpiecethroughsheardeformation. CNCGrindingisusedforfinishing workpieces that must have high surface quality (such as low surface roughness) and high-precision shapes and sizes. Since the dimensional accuracy of grinding is about 0.00025mm, in most applications, itisusuallya finishing process, which can remove relatively little metal and the depth is about 0.1 to 0.005mm. However, in some rough machining applications, grinding can remove large amounts of metal quickly. The CNC grinder consists of a power grinding wheelthat rotates atthe required speed and a base with a fixing device for fixing and guiding the workpiece. The grinding head can be controlled to move on a fixed workpiece, or the workpiece can be moved whilethe grinding head is keptin a fixed position. Using the hand wheel or digital control function of the cursor

calibration, the position of the grinding head or worktable can be controlled very finely.

G.H.Qin et al.[1] It was observed that the geometric accuracy of the manufactured workpiece mainly depends on the relative position of the workpiece with respect to the processing tool. A fixture is required to position the workpiece. Jing Yu et al. [2] experimented that the automation of fixture planning plays a vital role in improving fixture design and manufacturing efficiency. An automatic method for rapid fixture planning is proposed, which can determine three main clamping points based on geometric analysis. Sangui and Peters. [3] studied the influence of surface errors on the position and orientation of cylindrical workpieces in the fixture. Wu et al. Literature [4] proposed geometric analysis on fixture accuracy, fixture planning, fixture accessibility and fixture stability for automatic fixture planning. Song Rong literature [5] proposed a method to evaluate the positioning plan and assist the fixture designer to analyse and improve the design plan. S.Selvakumar et al. [6] It was observed that the deformation of the workpiece can be minimized by optimizing parameters such as the clamping force, the number of positioners and fixtures, and the positions of the positioners and fixtures. When the clamping force is the smallest, the deformation of the system is the smallest. The minimum clamping force required to hold the workpiece can be determined by the balance torque method and the Coulomb static friction law. To determine the deformation of the workpiece, the tool path is divided into five loading steps. The material removal effect is also considered.

II. METHODOLOGY AND SPECIFICATION

A. Hydraulic Steering Systems

Power steering gear is an important part of heavy-duty vehicle steering, which can provide higher steering force, reliability, comfort, and safety. This is not a mechanical connection between the steering column and the steering wheel, but a mechanical connection between the power steering unit and the steering cylinder through hydraulic hoses and pipes. Through the power steering device, the driver's steering operation can control the direction and pressure of the oil from the pump. The oil (left or right) flows into the steering cylinder, and the same amount of oil is returned to the oil tank. The steering wheel controls the direction, and the steering wheel rotates in proportion to the rotation of the steering wheel. Power steering devices are usually used in industrial vehicles, construction equipment, ships and servo systems that control direction and position.

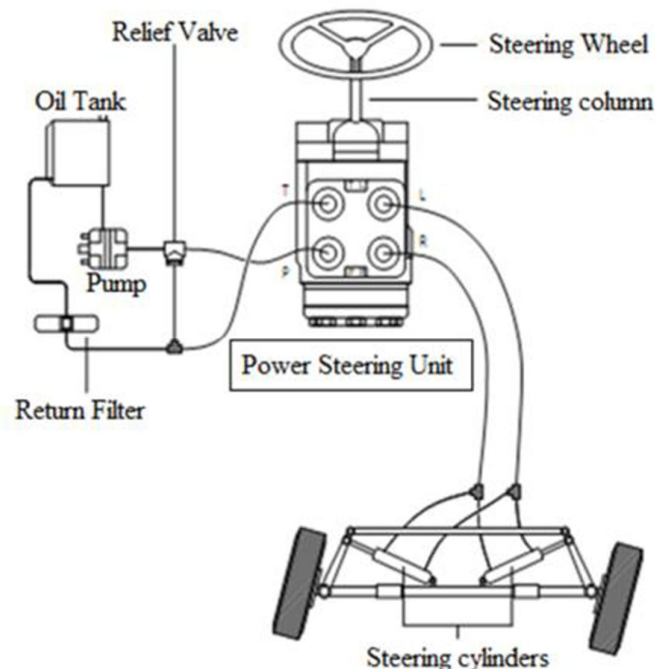


Figure 1. Typical Steering System

B. Apparatus

The following flowchart of the methodology is to be considered.

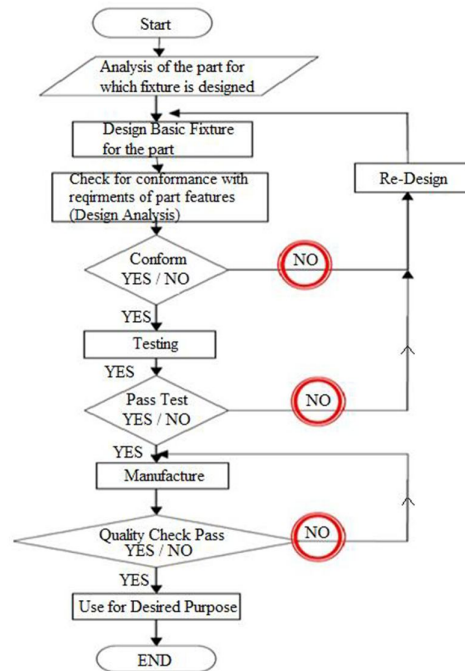


Figure 2. Typical flowchart of the methodology

C. Machine Specifications

- a) Maximum x-axis spindle movement=1000mm.
- b) Maximum z-axis length =300mm.
- c) Spindle speed=40,000 RPM.

Figure-3 shows MECCANODORA CIMAT C-661 which was a special purpose internal grinding CNC machine, which was used earlier to grind the internal surface of a bearing cage as shown in figure.4 to the required dimensions and surface finish as per the customers demand ($R_a = 5-6$ microns). When the project of modifying the meccanodora CIMAT C-661 ID grinding CNC machine was proposed, a study on the machine, process and modification planning was carried out. The company's requirement is to grind the internal surface of a rotary sleeve valve in an ID grinding machine to very high surface finish and accuracy and there was a requirement for a new ID grinding CNC. Since adopting a new machine would be too expensive the company thought of modifying the existing ID grinding C-661 CNC to general purpose ID grinding CNC which makes it cost effective and suitable to grind the internal surface of rotary sleeve valve and other cylindrical components.



Figure 3: Meccanodora Cimat C-661



Figure 4: Bearing cage

III. DESIGN AND VERIFICATION

A. Design and Modification of Fixture

The existing special purpose magnetic fixture and its accessories was removed from meccanodora C661 (as shown in figure 5) grinding machine and it was analyzed to study the various factors which had to be taken care during design of new fixture for valve sleeve. After dislodging the existing fixture, it was determined that the type of fixture was magnetic type. I.e., the bearing cage was held by this fixture by a normal magnetic force and the surrounding clamping mechanism helped the component to clamp and hold it rigidly. After removal of the old fixture, the area for mounting a new fixture was studied and various factors such as location system, clamping system, required level of accuracy, clamping force and rigidity etc. was taken into account. Based on the various factors there was a plan to design a collet type fixture for valve sleeve which could produce required level of clamping force and accuracy. Before going to the design of collet let us observe the space available for new fixture assembly for clamping valve sleeve.



Figure 5: Magnetic Type Fixture

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Figure 6: Space Available for Adopting New Fixture

The chuck is a sleeve with a cylindrical inner surface and a conical outer surface. The chuck can be pressed to a matching taper to shrink the inner surface to a slightly smaller diameter, thereby squeezing the tool or work piece that needs to be securely fixed. Usually, this is achieved by a spring chuck made of spring steel, which has one or more cuts (slits) along its length to make it stretchable. Another chuck design is to fix several tapered steel blocks (basically tapered gauge blocks) in a circular position through a flexible bonding medium (usually synthetic rubber or natural rubber), just like a star-shaped pen tip, Or the same as the jaws of the chuck).

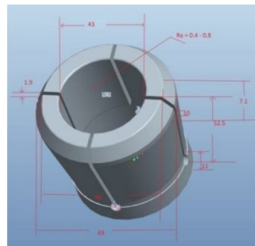


Figure 7: Standard Isometric View of Collet

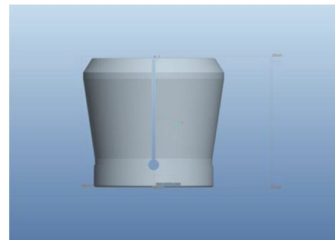


Figure 8: Front View of Collet

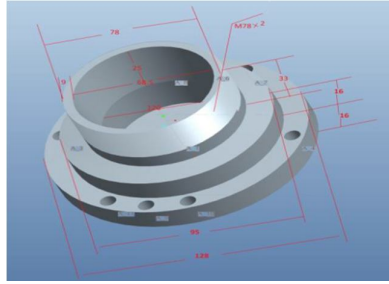


Figure 9: Standard Orthogonal View of Socket

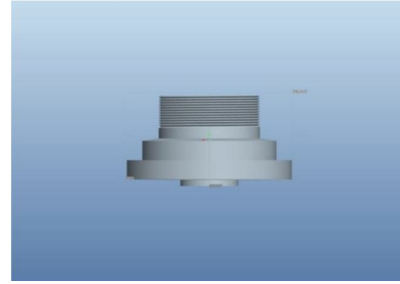


Figure 10: Front View of Socket

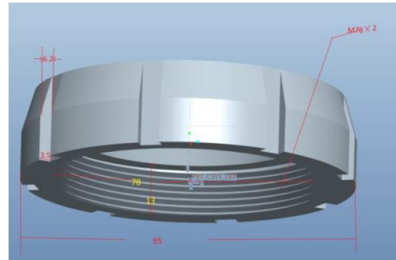


Figure 11. Standard orthogonal view of nut

Material Specification

Material properties:

Material – chrome vanadium alloy spring steel 0.50%C

From Design Data Handbook – Table 11.8, pg-153, we have the following Material Data.

Ultimate Strength – 1725 MN/m² or N/mm²

Elastic Limit (σ_y) = 1590 MN/m² or N/mm²

Modulus of Elasticity (E) = 0.206 × 10⁶ MN/m² or N/mm²

Density – 7800 kg/m³

B. Design Calculations

The Screw force calculation formulas from the machinery's handbook are as follows:

$$F_u = \frac{F}{\cos b} \tan(a + \rho')$$

$$\text{Torque} = F_u \frac{d_2}{2}$$

To calculate the clamping force on the component (valve sleeve) by M78×2 thread in a collet type fixture.

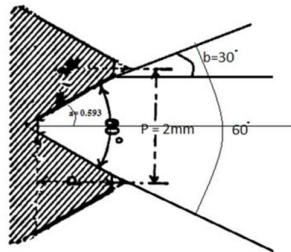


Figure 12: Basic Geometrical Parameters of V-Threads

Thread Angle = 60°

Pitch = 2mm

Lead Angle or helix angle (a) = 0.593

Flank Angle (b) = 30°
 $F_{max} = 98.1 \text{ N}$
 $T \sim 20 \text{ N-m}$

To obtain the relationship between the actuating torque and the peripheral force 'Fu' acting on the pitch diameter, from the formula:

$$F_u = 521.5 \text{ N}$$

$$F_t = 10 \text{ KN}$$

F_t gives the force exerted by the nut on the upper face of collet and acts uniformly in the direction parallel to the axis of collet.

To calculate the force 'F' transmitted on the outer diameter of the collet, we resolve the force along 'Ft' which gives the force necessary for clamping the required component.

The taper angle of the collet is found to be $\theta = 6.24^\circ$ which is obtained by the equation

Resolving the forces, we get:

$$\tan \theta = F/F_t$$

$$F = 1121.6 \text{ N}$$

Hence "F" gives transmitted force, which is nothing but the clamping force.

C. Check for Safety

Consider a single leaf of the collet, under going deflection due to the uniform load 'w'. Due to the tapered section of the collet leaf, let us assume that the leaf is rectangular bar subjected to uniformly distributed load with the following dimensions:

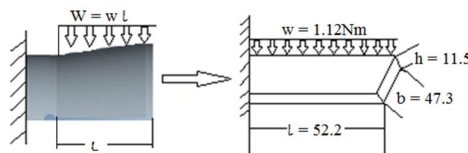


Figure 13: Application of UDL on A Single Leaf of Collet

The magnitude of clamping force is being applied per revolution.

Since this is a single start thread, we have

Therefore,
 We know that

$$\text{Lead} = \text{Pitch} = 2 \text{ mm}$$

$$\text{UDL} = w / \text{Pitch}$$

$$W = w \times l$$

$$W = 29232 \text{ N}$$

Maximum Bending Moment:

$$M = (1/2) \times W \times l$$

$$M = 381477.6 \text{ N-mm}$$

We know that,

Bending Stress or induced stress (σ_i):

$$\sigma_{\text{induced}} = M/Z$$

Where,

M- max bending moment (N-mm)

z- Section Modulus (mm^3)

But

$$z = bh^2 / 6$$

Where,

b= breadth of collet leaf (mm)

h= thickness of collet leaf (mm)

$$z = 1042.57 \text{ mm}^3$$

$$\sigma_{\text{induced}} = 381477.6 / 1042.57$$

$$\sigma_{\text{induced}} = 365.90 \text{ N/mm}^2$$

Factor of safety (FOS):

$$\text{FOS} = \sigma_y / \sigma_i$$

$$\text{FOS} = 4.35$$

Now,

taking FOS = 3

We know that

$$\sigma_{\text{allowable}} = \sigma_y / \text{FOS}$$

Therefore,

$$h = 9.55 \text{ mm} < 11.5 \text{ mm}$$

The designed thickness of collet is 11.5 mm which is greater than the obtained value of thickness. Hence the design is safe.

IV. CONCLUSION

The above work was carried on meccanodora CMAT C661 which was a special purpose internal grinding CNC machine.

The entire special purpose fixture was removed and replaced with a collet type fixture, whose function is to hold and clamp the rotary valve sleeve of the hydraulic steering unit.

Design and analysis of the fixture was computed and was successfully implemented on the machine.

Objectives achieved:

1. The Special purpose magnetic type fixture was removed and replaced with collet type fixture.

2. The old tapered form grinding wheel is replaced with friable white aluminum oxide grinding wheel to grind the inner surface of rotary sleeve valve.

Output Parameters after grinding:

The valve sleeve was taken out from the machine and was checked for the geometrical dimensions and surface finish which was the key objective of the project.

Three components (valve sleeve) were sent to gauge room and checked for the surface requirements and the average results were found to be

1. Surface Finish (Ra) = 0.5-0.6 (with the help of a surfometer)

2. Concentricity = 7 microns (with the help of a vertical CMM)

3. Cylindricity = 6 microns (With the help of a dial indicator)

Also, by employing the automatic clamping system with the help of a hydraulic cylinder attached to the end face of the collet, the human intervention can be avoided which are often error prone. This method improves the quality of finished part and reduces the manufacturing lead time there by increasing the production time.

This collet type fixture is cost efficient, compatible, and simple to operate then adopting a new grinding CNC. Hence this project provides maximum benefits in terms of customer and the company.

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