Design of work holding device for machining wheel hubs

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Abstract. Work holding device plays a significant role in the manufacturing of the component that is custom made for any operation. Over the past decade, there has been an increase in mass production and in turn, it has increased the demand for forged components. Wheel hub is an important component of an automobile. It connects the wheel assembly to the axle and the shaft. It is also responsible for the safety of the vehicle as well as the driver. The work holding is the primary issue of the machining operation to be challenged. The objective of this project describes the detailed definition of work holding devices and identifies several benefits that relate to the use of work holding devices in manufacturing. Some of it includes increase in production rate and cost reduction. Parts manufactured with precision and accuracy eliminates the inspection and quality expenses. It helps CNC or VMC machines perform operations by itself and serves the necessary purpose with minimal errors as there is not much of human interference. Implementing this kind of simple and effective mechanism in manufacturing sector drastically reduces the cost of labour and cycle time, thereby increasing the quantity and quality of production. The forged component already manufactured needs to undergo various operations with respect to its orientation. To perform required operation a special Collet system was designed and manufactured to the respective work holding.

Keywords: Wheel hub, Collet system, Design, Productivity

1. Introduction

The automotive industry, comprising of numerous auto parts, has witnessed a continuous research and innovation ever since the development back in the late nineteenth century. Today automobile sector is well known as one of the most dynamic fields, accounting for at least one in ten jobs in industrialized countries [1]. The industry integrates advanced technologies in vehicles to bring down emission levels and to ensure safety of its customers. However, in a world where material fabrication and metal heat treatment are outsourced, engineers need to be sure that the proper procedures have been performed on the material before it is used.

The purpose of the wheel hub is to serve as the glue between the wheel and the axle. Wheels are attached with studs to the hub assembly. The hub assembly then fits on the axle, which connects the wheel assembly to the rest of the car, acting like a bridge between the wheel and the entire vehicle, if one of its parts fails; it creates a ripple effect [2]. A hub is not a single piece of hardware. Instead, it needs a handful of other parts to do its job. Also, it is mounted with bearings that are cylindrical pieces that are packed with grease that reduces friction during wheel spin. The wheel hub bearing is used to slightly increase the fuel efficiency, providing smooth and safe ride for the passengers with Anti-lock Braking Systems (ABS) [3].

This research is related to the design of the work holding device for the manufacturing of wheel hub section that is too long [3, 4]. The design of this work holding uses the collet mechanism, improvements includes adding a pneumatic cylinder for up and down mechanism, for top clamping for the output loader on the top plate that helps in holding the component firmly for the operations to be performed [5]. As a result, the operator ensures proper alignment of the forged component being placed and reduces the rate of scrap after manufacturing that
occurs due to misalignment. This work holding facilitates the operator by providing good working area for the component manufacturing [6].

2. Methodology
In this work, the idea was to develop a work holding device for manufacturing wheel hub part at its best, which can be industrially manufactured to the exact dimensions of the drawing using the GD&T tools. A standard operating procedure was adopted till the final stage of manufacture. All the operations were carried out on CNC and VMC machine, incase of any burs, auto-deburring was carried out at specific speed. As it is a work holding device it is manufactured for a specific machine only [5,7]. The design of this fixture is drafted by keeping all the machining considerations, movements and factors and finally working of this work holding was evaluated and specific planning for mass production of four components in a single run was also studied.

2.1 Design considerations:
The points that are taken into considerations for designing of the work holding device are as follows:
1. The work holding device was made sturdy and to possess high durability. The operations included are drilling, roughing, tapping, chamfering. The operation parameters and the materials required is described in table 1 and table 2.
2. Alignment and clamping of the component to be precise and accurate.
3. Repetition of job is made easier by providing spring action to the orientation block mounted on Linear Motion Guide way.
4. All the operations should happen in a single run.
5. Inclusion of hydraulic top clamping to avoid unintended uplift of component while machining.
6. The movement of the collet system is restricted to avoid plastic deformation caused by pulling action.
7. T-bolt slots on base plate are identical with slots on machine bed.
8. The design should be rigid and robust to withstand vibrations as it may result to undesirable movement of component and damage the tools.
9. Two pin holes on the base plate to be made to match mountings on machine bed, which helps in achieving parallelism & perpendicularity of the entire fixture.

The component is a forged cast iron, which has density equal to 7870kgmm$^{-3}$ and weighs around 497 gram after machining as shown in figure 1 and figure 2.

2.2 Component specifications:

![Figure 1. Isometric view of manufactured component](image1)

![Figure 2. Front view of component](image2)

2.3 Operations to be performed:

| Table 1. Operations |
|---------------------|
| 1) 10.8mm Drill     |
| 2) Bottom Chamfer   |
| 3) Top Chamfer      |
| 4) M12 Tapping      |
2.4 Materials used for manufacturing of this work holding device are:

| SUB-PARTS                  | MATERIALS                  |
|----------------------------|----------------------------|
| 1. Base Plate with Pillars | Case Hardened Steel        |
| 2. Top Plate               | Case Hardened Steel        |
| 3. Collet Housing (4 nos)  | Spring Steel               |
| 4. Collet Inner Housing (4 nos) | Spring Steel             |
| 5. Linear Motion Guideways | Standard Length (120mm)    |
| 6. Standard Cylinders      | Standard Diameter (20mm)   |
| 7. Top Clamping Plate      | Case Hardened Steel        |

3. Description about the parts

3.1 Discussion on Design Parameters of the Wheel Hub:
In this fixture, collet acts as chuck. From figure 3, when collet gets squeezed in, the component will be held, it uses clamping pressure by forming a collar around the job, thus holding it firmly in the particular position. The clamping force is generated because of a tapered design on a sleeve and inner cylindrical surface. There are various kinds of collet, but all operate by being pressed over the job, resulting in both accurate alignment and static friction. But the collet mechanism is not suitable for holding every tool and all operations; it manages to self-centre, firm gripping, fast-chucking and steady clamping causing no indentation or scratch.

At the start of the design no optimization point is considered for the hub. Initially hub is designed and manufactured according to the requirement. The basic design of the hub is according to the bearing sizes.

The main objective of optimization is to perform machining operation and reduce the operating time for replacing the forged component to undergo the operation and increase the quality of components manufactured in a batch.

![Figure 3. Shows the Final Assembly of Fixture with the Component](image)

3.2 Base plate
The dimensions are specific and well defined for the manufacturing of the component and T-slots for easy mounting of fixture on the bed of the machine. The figure 4 shows the top view of the 2-dimensional drawing, total length of the base plate is 500mm and width is 400mm.
3.3 Top plate
The top plate stands 6 supporting pillars. The operations are carried out on the top plate. Space is provided to remove the machined burs from the operating area using air pressure blower nozzle. In the figure 5, we can see that the top plate is divided into 4 sections; it can be loaded with 4 parts at a time and be manufactured all together in a single run.

3.4 Collet housing and Collet inner housing
Collet body is made of spring steel. Spring steel has good elasticity when compared to other materials. Collet housing is the outer covering for the collet as seen in figure 6. In the work holding device, 4 Collet mechanisms can be used to increase the rate of production. The outer body helps the operator to identify the exact location to place the part to undergo respective operations. Collet inner housing as shown in figure 7, helps in holding the part firmly and does not allow any misalignment while machining. There is a taper angle of 14° and the taper length being 42mm, Colette pulls and squeezes the part to stay within the work holing and not let it jump away when it is operated under high speed and force.
3.5 Linear Motion Guide ways
Linear Motion Guide ways acts as an orientation block and is manually designed for the fixture as shown in figure 8, known as the reference slide. The front side of orientation block is of hexagon is shape. They help in movement of linear motion by spring action like in figure 9. This helps in orienting the component with the fixture once its placed, any slight corrections is managed by the orientation block as shown in figure 10.

3.6 Top clamping plate
From figure 11, Clamping plate is specifically designed to not undergo any mis-orientation of the part on the fixture when it is loaded. It also helps the operator to identify whether there is any obstructions or any miss-orientations of the part. In figure 10, the top clamp is attached to a standard cylinder of 20mm diameter and is mounted on them. There is hydraulic movement of cylinder while clamping and unclamping. The mechanism of the same is as shown in figure 12.
4. **Final Assembly of Fixture**

From figure 13, figure 14, and figure 15, gives a detailed view of the assembly with all the subcomponents being mounted can be observed. This fixture is 500 mm x 400 mm in size. The height of the pillars is 76 mm. The fixture rests on the bed of the machine from where the operations are done. The whole assembly is manufactured keeping into all the mechanical properties into considerations. The cylindrical pillars with M8 tapings are fastened onto the top plate for easy removal and they are welded on the surface of the base plate. The fixture is designed with precision and accuracy considering necessary design parameters.
In figure 13, the collet undergoes compression; its diameter gets reduced when the machining operation begins. The bottom pad acts as the butting surface to the component. Three holes are provided so that it can be bolted to the top plate.

Figure 14. 2D drawing of the fixture  Figure 15. Top view 2D Assembly

The above figure 14 shows the single assembly of the work holding device. The component here is mentioned. The above figure 15 shows the full assembly of the work holding device. This is work holding device manufactures up to 4 components in a single run as shown in figure 16, hence it increases the rate of production also.

Figure 16. Shows the manufactured assembly of work holding device without the component

4.1 Procedure
This fixture is made of case-hardened steel and mostly spring steel, the T-slots provided on the base plate helps in mounting the work holding on the datum of the machine. This work holding device was very much useful in the VMC and CNC. The objective of this paper is to show different machining operations, orientation and alignments of the components adopted. Firstly, the operator picks up the component and places it on the collet inner housing, after which due to the compression mechanism adopted by the collet on the inner diameter helps it get firmly mounted. The component has 3 flanges, due to this while performing drilling operations at high speed there is occurrence of miss-alignment from the work holding, to stop that standard cylinders are used which act as top clamping with hydraulic action tightly holding the component with the work holding. The total time taken by the operator to pick and place, with exact orientation of the component was less than 22sec for all the 4 components, this would increase the cycle time in mass production while manufacturing, and eliminate the scrap [8]. By reducing the time taken for the components to be aligned and oriented there would be reduction in total cycle time of the operation. Thus, providing more time for production of more component in the course was observed [10].

4.2 Discussions
The design of fixture mainly depends on the type of operation it performs as well as the machine to be considered. They help in eliminating the time required for special set-up time for every work piece, thereby increasing production in the batch and assure that every work piece manufactured does not exceed
the tolerance limit. With the help of collet, some of the repetitive operations like marking, punching before drilling, positioning according to exact orientations and precise alignments while setting up a new workpiece are eliminated. Henceforth, increasing the technological capabilities of machine tools by setting higher values of machining parameters like cutting speed, depth of cut and rate of feed because of the rigid clamping [9].

5. Conclusion:
The purpose of this research work is to design and manufacture the work holding device for wheel hub for the car and also to provide a detailed study in the process taken to reach the final design of the work holding fixture. The main objective was to assure the precise orientation of the component, which helps in improving the quality of the product and reduces the scrap rate. With the overall design being carefully examined in advance, the manufacturing process is controlled closely, and design features are proven effective within the performance requirement.

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