Design, Modelling and Manufacturing of 16 Cylinder Hydraulic Fixture with Automated Clamping System

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Abstract. The function of a jig and/or fixture (fixturing system) is to hold a workpiece firmly in position during a manufacturing process. It is seeming that almost all the literature of fixture is focused on principles and theoretical aspects of fixture design. This raises a question of the practical value of fixture research. There is a clear demand for designing and manufacturing fixture for real industrial component and more research in computerized fixture design in such fields. The present research work satisfies this demand by deploying the fixture design task into an overall manufacturing process to obtain best fixture design solution for real industrial component. The component is rear flange of gear case widely used in automobile industry, made up of cast iron. The major operations to be performed are drilling and milling. The research includes design and manufacturing of a fixture with automated clamping system, which provides location and clamping arrangement for machining 4 components in one cycle on VMC 640 of pallet size 800 mm x 500 mm. Machine tools, material handling devices, transport and other mobile equipment, aviation systems, etc. do use hydraulic systems, but application of hydraulic principles in fixture is of uncovered area till now. This paper includes designing and manufacturing 16-cylinder hydraulic fixture with automated clamping system for machining rear flange on VMC. The important details of the part and fixture are included in each section along with 2D drawing and 3D view of finished component and fixture assembly using Creo 2.0. Fixture is not only designed but manufactured also, it sets the classical example of design for manufacturing.

1. Introduction

Fluid power technology is passing through a revolutionary change due to the integration of electronics as a control medium for hydraulic components and systems. Wide application of hydraulics is a recent trend in industries. A few decades earlier in the western world, the use of oil hydraulic system as a means of power transmission in modern machines was evolved. There is a great deal of urgency and importance to master the art of its application and maintenance in Indian industries. This research paper includes design, modeling and manufacturing 16-cylinder hydraulic fixture with automated clamping system for machining rear flange on VMC. While designing this research work, good number of research papers written by renowned authors and experts are referred. Selection and positioning of locating points method of fixture design is proposed by Menassa, R., and Devrise, W. Different types of application of fixture considered are for prismatic workpieces that use the 3-2-1 locating principle as the general structure of the fixture [1].
Accuracy of the work piece is decided by the positioning and orientation error. Elastic deformation of loaded fixture–work piece due to the displacements of the rigid body work piece contacts strongly influence the ability to accurately locate a work piece in a machining fixture [2].

The present volume of this research work introduces a novel concept of hydraulic fixture and automated clamping system to achieve desired objective of significant improvement in the production rate and reduction in non-productive time. The input is the CAD model of the work piece and the output is the CAD models of the needed fixtures [3].

Hydraulic clamping system of a special CNC machine tool to design hydraulic cylinder to ensure the safety and reliability of workpiece was introduced by Ke Yanga, Shangjun Guan, Cunlong Wang. Clamping automation of the workpiece was guaranteed by means of effective design of oil cylinder and theoretical calculations [4].

Hydraulic clamping system with sensor integration was invented by Berend,Dahlmann and Kiesner[5-6].The machining process of a complex part is to be designed by using hydraulic clamping system. A case study of setup time decreases and steps of machining process ensuring the level of quality initially desired is very well described by Claudio costa and R.P.Martinho[7].

The following section presents the real-time research work of designing and developing 16-cylinder hydraulic fixture for machining rear flange on VMC 640 of pallet size 800 mm x 500 mm. The important details of the part and fixture are included in each section along with 2D drawing and 3D view of finished component and fixture assembly using Creo 2.0.

2. Design and Manufacturing of Hydraulic Fixture

2.1. Problem Statement
“Design, modelling and manufacturing of hydraulic fixture with automated clamping system for machining rear flange on VMC 640 of pallet size 800 mm x 500 mm. Drilling and milling are the major operations to be performed.”

2.2. Component Details
The component is rear flange of gear case, weighing 5 kg, made up of cast iron, widely used in automobile industry and in raw material form is forged. Machining operations are to be performed on six faces – 4 sides, top and bottom face. The operations to be performed are profile milling (17 mm x 3 mm), drilling (3 holes, $\phi$ 9 mm), pocket milling (17 mm), spot facing (19.8 mm x 0.3 mm deep), chamfering of holes (top and bottom profile).

2.3 Design of fixture
Following the very basic principle of location by machined surface, bottom face of the component is used for machining as it is received finished in the raw material form. Base plate, two rest pads operated by hydraulic cylinder, two orientation cylinders, one orientation pad and one spring plunger are used to achieve complete location. Base plate is used to provide the plane to rest the component and it has same profile as that of the component to accurately locate the component. Two hydraulicallyoperatedrest pads and two orientation cylinders are used in a plane perpendicular to base plate to locate the component according to principle of mutually perpendicular planes. Orientation pad pushes the component with the help of hydraulic cylinderagainst rest pads. Two hydraulic clamps are used to clamp the component.

Fixture assembly locates and holds four components in one cycle increasing productivity. So total 16 cylinders are required to operate 8 hydraulic clamps and 8 rest pads for all four components. Figures 1 & 2 show detail drawing and modeled view of finished component. Figure 3 showstwo-dimensional view of hydraulic fixture assembly and figure 4 shows 3D view of fixture assembly for one component with locating and clamping arrangement. The fixture assembly is shown in figure 5.
Figure 1. Detailed drawing of finished component

Figure 2. Modeled view of finished component
Figure 3. Two-dimensional view of hydraulic fixture assembly

Figure 4. Three-dimensional view of fixture assembly for one component with locating and clamping arrangement
2.4 Analytical calculations
Calculation is shown for drilling operation. The cutting conditions are as under.
Diameter, D=9 mm
Feed per revolution, S=0.18 mm/revolution
Material factor, K=0.55
Thrust force,

\[ T_h = \frac{1.17 \times K \times D}{(100 \times S)^{0.85}} \]

\[ = \frac{1.17 \times 0.55 \times 9}{(100 \times 0.18)^{0.85}} \]

\[ = 0.492 \, kgf \]
\[ = 4.82652 \, N \]

Contacts and constraints are added in figure 6. Figure 7 shows Von Mises stress analysis, displacement and strain energy analysis of component. Table 1 & Table 2 shows material of the components of fixture assembly with mechanical properties, chemical composition and endurance limit. Figure 8 shows photograph of manufactured fixture.
### Table 1. Chemical composition of material

| Constituent   | Percentage       |
|---------------|------------------|
| Aluminum (Al) | 79.3 - 88.4      |
| Silicon (Si)  | 9.5 - 11.5       |
| Copper (Cu)   | 2.0 - 3.0        |
| Magnesium (Mg)| 0.1 - 0.3        |
| Zinc (Zn)     | ≤ 3.0            |
| Iron (Fe)     | ≤ 1.3            |
| Manganese (Mn)| ≤ 0.5            |

### Table 2. Mechanical properties of material

| Property                        | Value          |
|---------------------------------|----------------|
| Hardness                        | 80 BHN         |
| Ultimate Tensile Strength       | 310 MPa        |
| Yield Tensile Strength          | 152 MPa        |
| Modulus of Elasticity           | 71 GPa         |
| Fatigue Strength                | 131 MPa        |
| Shear Strength                  | 172 MPa        |
| Melting Point                   | 571°C          |

**Figure 6.** Contacts and constraints

**Figure 7.** Von Mises stress analysis, displacement and strain energy analysis of component
3. Conclusion

Unique approach of hydraulic fixture is used in the present research work, which results into increase in productivity by saving time. 15 to 20 seconds per clamp are required for manual clamping and de-clamping. Increase in non-productive time presents a serious problem in case of a fixture with multiple clamping points as more than one minute will be required for clamping and this time will still be more for uniform clamping.

Automatic clamping using hydraulic cylinder will reduce non-productive time significantly. Another worth-noting advantage of hydraulic fixture is reduction in fatigue of operator. The efficiency of operator decreases due to fatigue in manual clamping, which may result in reduction in safety and less clamping torque at the end of the shift, specifically for the elderly operators. By introducing automatic clamping system, such problem can be overcome.

Hydraulic fixture and automated clamping improve quality of clamping as an operator can operate all clamps at the same time with control over clamping force for dimensional accuracy to have a consistent clamping force without vibration during operation.

Fixture is not only designed, but manufactured also; it sets the classical example of design for manufacturing.

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