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Design and Fabrication of Keyway Cutting Fixture for Gears

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Abstract - *The project aims to provide a solution to the difficulties faced in making keyways in various types of gears: Spur, Helical, and Bevel. It focusses on developing an adjustable fixture mechanism which incorporates versatility as its main feature. The assembly comprises of base plate, fixed plate and movable plate. The movable plate is attached with a hydraulic actuator for the ease of clamping. The actuator is so designed that it can exert a force of 2 KN to hold the workpiece. The project involves the design and fabrication of keyway cutting fixture setup and finally the testing of keyway cutting on the fixture assembly for various gears.*

Key Words: **gear, keyway, fixture, hydraulic actuator, hydraulic circuit**

1.INTRODUCTION

Gears are mechanical components used for speed enhancement or reduction and have myriad applications. Fixing a gear on the shaft is quite expensive and a time consuming process. Designing a fixture which would help in making a keyway for various gears would be a boon to the industry. It would not only save time but also would be economical and feasible.

Keyways are square channels which provide a strong connection between the gears and the shaft when the key is inserted between them. The basic function of gears is to transmit power. For this, the shaft has to transmit power to the gear in the following two ways: integrated shaft type system or keyway system. Since integrated shaft type system is complex and expensive, most of the small applications are based on the keyway systems. Hence making a keyway in the gear becomes mandatory for such applications. Currently, keyway cutting is being done by various methods like broaching and shaping.

Though broaching has been proved to be the most widely used approach, there is limited versatility in terms of types of gears, that, it can cut a keyway into: only one fixture per type of gear. Fixtures are work holding or supporting devices used in manufacturing industry to reduce the cost and increase the quality. They are used to securely locate and support the work, ensuring that all parts produced using this fixture will maintain conformity and interchangeability.

The project focuses on the design and fabrication of versatile keyway cutting fixture which can be installed on a shaper machine. It will incorporate cutting of keyways for spur, helical and bevel gears of different dimensions. This will not only make the manufacturer's job easier, but also cut down on its manufacturing cost and in-turn on the selling cost of the particular gear with a keyway.

2.DESIGN AND DEVELOPMENT

The overview layout of the project along with the components, design calculations with its assumptions are shown below.

2.1 Components and Assembly of Initially Proposed Design

1) *C Frame*: C frame is a frame used for clamping of mild steel used for holding the gears firmly and securely during the cutting action. A circular arc of angle 85° is used for its design because it would provide more surface area for clamping gears of diameter up to 85 mm. The thickness of the 'C' frame is 30 mm as it was the optimum thickness to hold the gears. The material used is Mild Steel.
2) *Carriages*: A rectangular block of 300×100×156 mm is the basic dimension of the carriages which is hollow centrally by depth of 56 mm. The material used for the component is Mild Steel.
3) *Bed*: The complete assembly stands on the bed as shown in figure 1. The dimensions of the bed are 500×200 mm and hollow centrally to accommodate carriage nut. The dimensions are obtained as per the size of the shaper machine mentioned where the T-slots would smoothly slide in to the shaper machine's bed. The material used is Mild Steel.

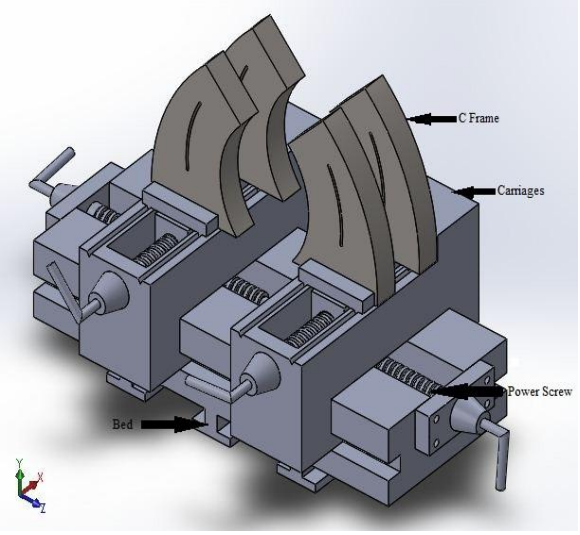

Fig-1 Assembly of the Fixture

2.2 Components and Assembly of Revised Design

1) *Base Plate and Fixed Plate*: The complete assembly stands on the base plate which has a stepped rectangular slot in the middle for the movement of movable plate used for clamping. The fixed plate is bolted at one end which transmits the cutting force to base plate. The material used is Mild Steel. The dimensions of base plate and fixed plate are 170×150×30 mm and 170×120×30 mm respectively.
2) *Movable Plate*: The movable plate is actuated with the help of a hydraulic actuator and it moves through the given slot of the base plate. The material used is Mild Steel. The dimension of the plate is 170×120×24 mm.

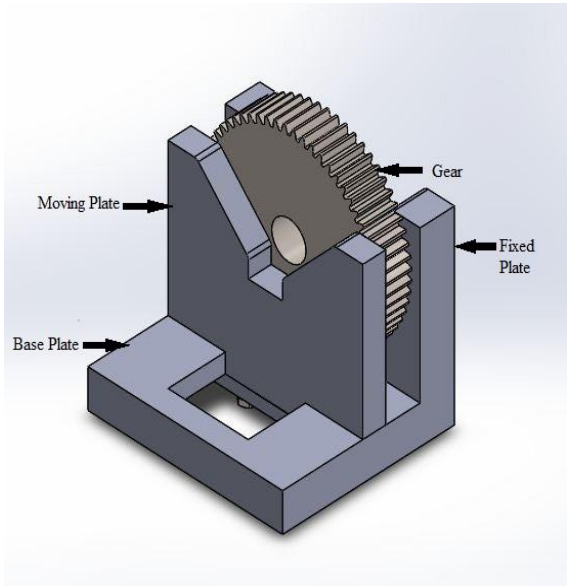

Fig-2 Revised Fixture Assembly

2.3 Components and Circuit Diagram of the Hydraulic System

The hydraulic system is used for clamping the workpiece which was available in the college workshop and it consists of the following components:

1) Hydraulic Actuator.
2) Common Port.
3) Direction Control Valve.
4) Relief Valve and Pressure Gauge.
5) Motor and Pump.
6) Oil Reservoir and Hose Pipes

For the ease of operator and to save the time required for clamping the gears, the revised model of the fixture incorporates a hydraulic clamping system using hydraulic actuator arrangement.

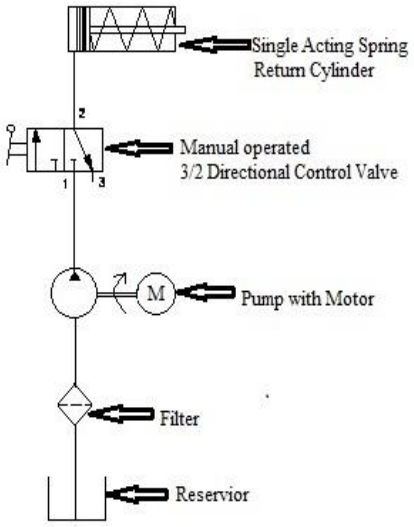

Fig-3 Hydraulic Circuit Diagram

2.4 Actuator Selection Calculations

Metal Removal Rate = d x Fr x Vc x 12 (in. /ft.)
Where d = Depth of Cut (in.)
Fr = Feed Rate (in.)
Vc = Cutting Speed (sfm)
Q = 0.0787 x 0.0472441 x 49.5 x 12
= 2.209685 cu. in. /min
Horsepower required = metal removal rate x unit power

Where Hp = Horsepower required (cu. in. /min)
Q = Metal removal rate (in. /ft.)
P = Unit power
Or Hp = 2.209685 (cu. in. /min) x 0.3 (Hp/cu.in/min)
= 0.6629055 Hp

Resultant cutter force = Hp x 33000 / cutter speed (sfm)

Where Fc = Resultant cutter force (pounds)
Vc = Cutter speed (ft-lbs/min/Hp)
Or Fc = (0.6629055 x 33000) / 49.5 sfm
= 441.937 pounds
= 1.96583 KN

3.ANALYSIS OF THE FIXTURE

The analysis is performed on the fixture to analyse the stresses developed on the fixture and any deformation occurring on the fixture due to the cutting force.

3.1 Stress Analysis and Total Deformation

Stress analysis on the fixture assembly was performed on ANSYS. The following constraints were given to various components of the fixture assembly.

- Fixed support – Bottom of the base plate and back side of the fixed plate.
- Pressure – 0.1206 MPa of pressure applied on the surface of moving plate which is common to gear.
- Force – It is applied on the area where cutting of keyway takes place with magnitude 950 N.

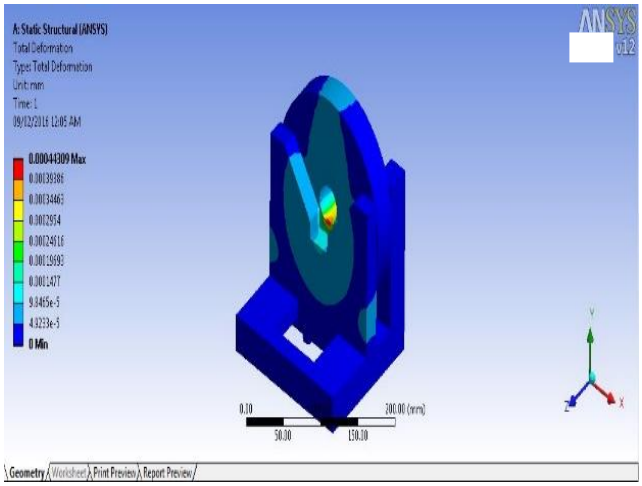

Fig-4 Equivalent (Von-Mises Stress) Stress

The above figure 4 shows the stresses generated on the fixture and the gear due to the cutting action of the shaper machine. The maximum stress generated is on the area where keyway is cut with magnitude 5.084 MPa while the stress on the remaining portion of gear and the fixture assembly is negligible.

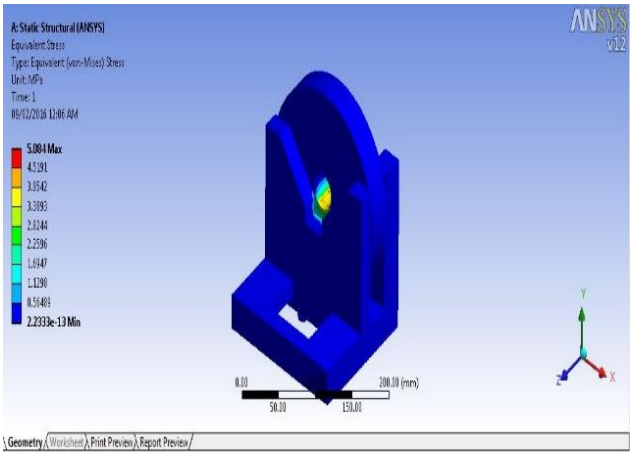

Fig-5 Total Deformation

The above figure 5 shows the total deformation generated on the gear. The deformation developed is 4.4309e-04 mm which is very negligible and does not affect the fixture.

3.2 Shaper Machine Specifications

Shaper machine is used for fixing the fixture and for making keyway in the gears which has following specifications:

- Maximum horizontal traverse of table
= 600 mm
- Maximum vertical traverse of table
= 350 mm
- Maximum distance of table to ram
= 400 mm
- Maximum travel of the tool side
= 150 mm
- Length and width of the table top
= 350 mm
- Length and depth of the table side
= 400 mm
- Number of ram cycle per min
= 12 to 75
- Number of feed
= 4
- Cutting to return stroke ratio
= 2:3
- Power input of motor
= 2.2 KW

4.FABRICATION OF THE PROJECT AND FINAL SETUP

After all the individual components in the project were procured and fabricated, the construction of the project setup was started according to the plan. The prototype of the project was constructed according to the design specifications. There were several constructions, fabrication and assembly challenges that were faced while designing the

setup. Initially the fixture was to be mounted on the bed of the shaper machine which was done by drilling holes of ½ inch in the base plate of the fixture. Then the bolts of ½ inch was inserted into the hole which got fixed in the T-slots specially designed for the shaper machine. Now there was a task of fixing the hydraulic cylinder to the movable plate at its centre of gravity for smooth movement of the movable plate. So the nut of 30 mm diameter was welded to the movable plate and then the hydraulic cylinder was attached with the movable plate. There was stacking of scrap material plates which was used underneath the hydraulic cylinder for its proper positioning. Eventually now only one task was remaining of fixing the hydraulic cylinder to the bed of the shaper machine so that it is secured firmly to the shaper bed. For clamping purpose c-shaped frames were used which had a hole drilled in the side plates of 1/8 inch and it was fixed to the shaper bed by using nut and bolt assembly of 1/8 inch and 50 mm long. The hose pipe was connected to the actuator with the help of nipple which had a diameter of 19 mm. Then a centring rod of 30 mm diameter and 150 mm length was used for the full proofing purpose. The entire setup is as shown in figure 6 along with all the hydraulic connections.

Fig-6 Final Setup

5.TESTING AND RESULTS

The following parameter were required for the cutting of keyway in gear.

Depth of cut - 4 mm
Stroke length - 170 mm
Feed rate - 1 mm/ min

Table-1: Testing Results

Components	Material	Gear Size (mm)	Cutting Time (min)
Spur Gear	Mild Steel	160	3 min 56 sec
Helical Gear	Mild Steel	110	3 min 30 sec
Bevel Gear	Mild Steel	125	3 min 33 sec

Installation time required is 4 min and the time required for clamping is 4 sec. The overall time taken from installation to cutting operation is around 8 min.

6.CONCLUSION

The entire fixture assembly can be used as an alternative in small scale workshop where the floor space available is less. Against the traditional method of broaching as a keyway making method in gear, requires one fixed setup for particular size and type of gear while the designed fixture is versatile in terms of gears, their size and also about the time required for cutting. The hydraulically operated fixture can prove beneficial to the workshop where hydraulic setup is already in use. The clamping force exerted by the hydraulic cylinder can be calculated and accordingly the design of the cylinder can be done. This would provide the hydraulic cylinder with required clamping force. Thus it can be concluded that the objective of secure location of workpiece, its clamping and cutting the keyway as per the required dimension is achieved and also multiple gears up to 2 gears at one time can be clamped and keyway can be made in them.

ACKNOWLEDGEMENT

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