

Design, Development and Analysis of Clamping Force of a Cylinder of Fixture for Casing of Differential

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Abstract: Jigs and fixtures play a vital role in manufacturing process in order to have interchangeable parts in mass production. The fixtures are work holding devices used to locate and fix the position of work pieces for machining, assembly, inspection, and other operation(s). Locators are used to determine the orientation and position of a workpiece, and clamps exert clamping forces on the workpiece so that the workpiece is pressed against locators and resting pad.

The present carried out work deals with the design, development and analysis of clamping force of a cylinder of fixture for a differential case. The cutting forces involved in the operations are taken into consideration for designing the fixture. The present fixture designed is hydraulic operated. In the design process based on the geometry of the component to be machined, the machine, the table layout and corresponding clamping slot positions are then selected. Computer aided fixture design of fixture assembly is carried out using modelling software and Finite element analysis of fixture and cylinder block is carried out using ANSYS Static workbench software. Clamping forces are calculated for hydraulic pressure and are taken into consideration during Finite element analysis (FEA). Analysis is carried out and at different tool positions, reaction forces are calculated along with the maximum stresses and deformation occurred and modification in fixture assembly model accordingly is done which creates optimum fixture assembly design to get manufactured.

Keywords: Fixture, Design, FEA, Clamping forces, Stresses etc

1. INTRODUCTION

Fixture is a vital tool which holds a work piece in a proper position during manufacturing process. For clamping and supporting the workpiece on its position, device called fixture is used. Positioning, frequent checking, non-uniform quality and individual marking in manufacturing process is eliminated by fixture. Fixtures of different kinds are used in the manufacturing process is eliminated by fixture.

Differential Case: Casing of differential or Differential Case is used in this project to design a machining fixture which is used in automobile vehicles. Transmission case or differential case in vehicles is used to cover the parts like flywheel, clutch (or) torque converter of the transmission on vehicles powered by internal combustion engines. This case is bolted to the engine block; the starter motor is usually mounted at the engine end and engages with a ring gear on

the flywheel. On the opposite end to the engine is usually bolted to the gearbox.

What is Hydraulic Fixture

Hydraulic Fixture is a clamping system which utilises liquids of high pressure for power clamps and holding of work piece in place. Hydraulically clamped fixtures have an edge over manually clamped fixtures. In most cases, they will not enhance costs for manufacturers making them to justify the pre- investment for a hydraulic clamping system.

- The major advantage of hydraulic work holding is time saving in clamping & de-clamping the component(s). It reduces cycle time paving way for increase in manufacturing capacity & cost reduction.
- In hydraulic fixture, forces in clamping are constant resulting in precision positioning & clamping. This ensures sequential processing procedures & assured quality.
- Parts are clamped with the same clamping force for every cycle & in the same location eliminating the part deflection variability from clamping forces and improving process stability.
- More parts shall fit within machine envelope due to the high clamp forces generated with small hydraulic components. Thus paving way for more productivity.
- Eliminates human error due to assurance that every clamp will be actuated with every cycle, eliminating human error and missed steps. Also allows operators to be consistently more productive with less effort hence increase ergonomic efficiency.

2. LITERATURE REVIEW

Following are the some of the literature reviewed for the development of fixtures:

Sridharakeshava K. B. et. al., [1]: Has discussed about the General Requirements of a Fixture which includes constraints of Deterministic location, contained deflection, geometric constraint in order to maintain the work piece stability during a machining process. They also discussed three broad stages of fixture design, Stage one deals with information gathering and analysis, Stage two involves product analysis, and Stage three involves design of fixture elements.

Raghu and Melkote, [2]: Workpiece location error is done by consideration of the fixture elastic deformation and geometric error of the fixture and workpiece due to fixturing forces. For modelling of workpiece, location error.

Prabhakaran [3]: modelled the fixture-workpiece system by consideration of workpiece as elastic body. The clamping force is modelling as point force. Static analysis is used if the elastic deformation of the workpiece is under the machining.

3. PROBLEM STATEMENT AND METHODOLOGY

The main objective of work is to Design, Development and Analysis of milling fixture for Differential case or case of differential component in automobile assembly. In this required work, modelling is carried out and cutting force acting and clamping force on the cylinder component is calculated and analysed using Ansys to determine the safe working condition of the fixture.

The main skeletal objective of fixture design is:

- a. Design for performance of component.
- b. Design for Manufacturability and Assembly.
- c. Increasing of production rate by designing the fixture that will produce parts as fast as possible.
- d. Good fixture layout selection for the design which helps in ease of manufacturing of the fixture and to minimize the defects.
- e. Detailed study and analysis of manufacturing process of various parts that are used in the fixture
- f. Use of predictive analysis tool, Ansys used to simulate the force(s) acting on the fixture cylinder during machining and then to utilize the results obtained for force reaction.

Methodology is a systematic approach for the realization of total task. It consists of the following detail:

Study of the part: The part study is the most essential and the initial step for the planner. The segment drawings are examined to remove the extreme measure of data, measurements, finding and clamping zones of fixture parts.

Geometric model of considered part: Geometric modelling of part is done utilizing Co-Create considering all the basic measurement, tolerance and results required.

Plan and Calculations: It is completed to decide the different outline parameters that decide force reaction in X, Y and Z direction and total force reaction affected on the part amid processing operation.

Selection of tooling materials: The materials utilized as part of the assembling of installation changes relying upon the applications of tool selected.

Solid demonstrating of the apparatus: 3-D displaying of the whole shape is done .For the better comprehension of 2D drawings and representation, demonstrating has been finished. The required measurements are dictated by figuring, which is utilized amid demonstrating of the instrument.

Analysis: Analysis for Total static structural force reaction and static structural force reactions in X,Y,Z directions (in N) is conveyed utilizing Ansys to check the best possible choice of clamping

Cost Estimation: Tool cost estimation is important, particularly for little and medium clump of generation runs, where the expense of an instrument proclaims to a critical rate of the item cost advancing.

4. RESULTS AND DISCUSSIONS

Clamping Forces Calculations by Analytical and FEA method:

The clamping forces by numerical and analytical methods are to be calculated at required hydraulic pressure and various forces input so that from validation final result we get clamping forces values which are used in analysis of fixture-workpiece designs by using ANSYS workbench software so as to obtain optimized fixture workpiece design having less deformation and less von-misses stresses.

Clamping Forces by Analytical Method:

To calculate clamping forces by Analytical methods, we consider a piston and clamp lever linkage connection in that, first and foremost we should calculate the resultant piston force acting on clamp lever when hydraulic pressure is applied to piston head and after that we assume clamp lever as a rigid element with mass almost negligible. The reaction forces calculations, by considering free body diagram and clamping force along with hydraulic pressure is shown in figures 1 and 2 respectively.

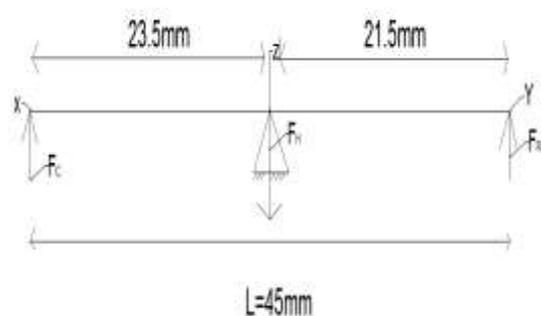


Fig.1: Reaction forces free body diagram

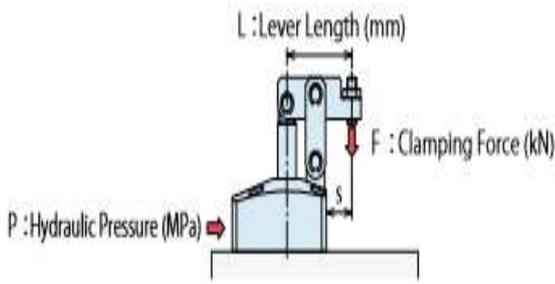


Fig.2: Clamping force along with hydraulic pressure

From above Fig.1 forces acting on piston by hydraulic pressure are as follows; the selected cylinder inner diameter $D_i = 45\text{mm}$; Rod diameter = 20mm ; outer diameter $D_o = 65\text{mm}$

1. Force acting on piston head by hydraulic pressure: $F_1 = P \times A_i$

$$= (\pi/4) \times D_i^2 \times P$$

$$= (\pi/4) \times 45^2 \times 3.5 = 5563.68\text{N}$$

2. Force acting on piston head by cylinder head (Opposing force of piston):

$$F_2 = P \times A_o = (\pi/4) \times D_o^2 \times P$$

$$= (\pi/4) \times 65^2 \times 3.5 = 11608.18\text{N}$$

3. Net force acting on the piston rod: $F_R = F_2 - F_1$

$$= 11608.18 - 5563.68 = 6044.5\text{N}$$

By considering clamp lever as a rigid element, with negligible mass so the forces acting on the rigid beam where Z is the point lever is hinged, F_H is hinge reaction force, Y is the point where net piston force (F_R) is applied, X is the point where clamping force (F_c) is applied.

So from Free Body Diagram;

From Newton's First Law of Equilibrium;

$$\Sigma V = 0$$

$$F_c + F_R - F_H = 0$$

Also, by taking moments at C = 0

$$\Sigma M_c = 0 \text{ (Clockwise = +1);}$$

$$(F_c \times 23.5) - (6044.5 \times 21.5) = 0$$

$$23.5 F_c - 129956.75 = 0$$

Therefore; $F_c = 5530.07\text{ N}$ or 5.53 KN

Clamping Forces by FEA Method:

To calculate Clamping forces by FEA Method for hydraulic pressure of 3.5 MPa and force of 5570N using ANSYS software, we consider fixture clamp design model from CAD software. Therefore, for FEA import piston clamp lever CAD model in ANSYS Static workbench and define contacts between piston, small pin and clamp lever respectively.



Fig.3 (i): Cylinder clamp assembly

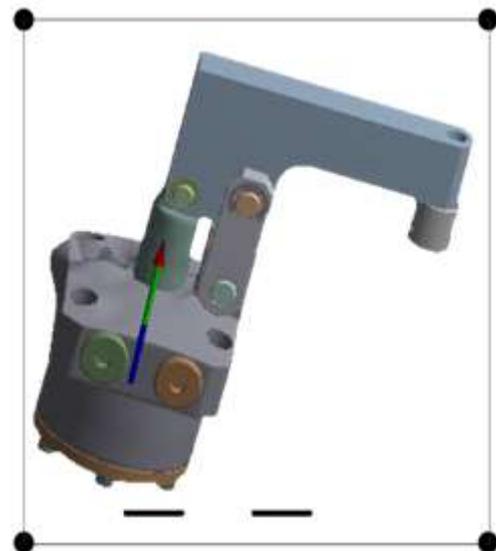


Fig.3 (ii): Static structural force reaction



A-Force applied

B- Fixed support

Fig.4: Reaction forces Boundary conditions

Time [s]	Force Reaction (X) [N]	Force Reaction (Y) [N]	Force Reaction (Z) [N]	Force Reaction (Total) [N]
1 / 1	-842.98	-5566.3	236.06	5634.7

Fig.5: Force reactions in X, Y, Z Directions and total (in N)

From above numerical and analytical calculations we get following results of clamping force (FC) for a given hydraulic pressure and force applied.

Force reaction (X) N	Force reaction (Y) N	Force reaction (Z) N	Force reaction (Total) N
842.98	5566.3	-236.08	5634.7

Clamping force reaction		Total force reaction	
Theoretical	5530N	Theoretical	6004N
ANSYS	5560N	ANSYS	5630N
%Error	0.54	%Error	6.8

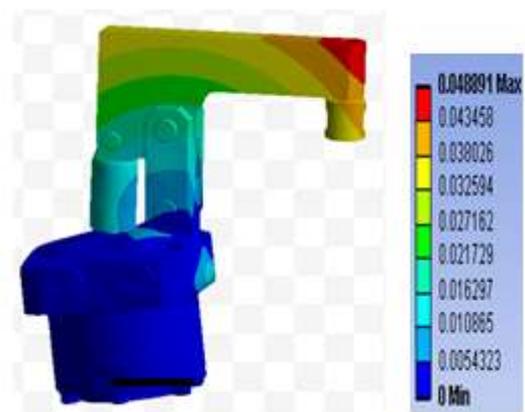


Fig.5: Total structural deformation of cylinder clamp assembly

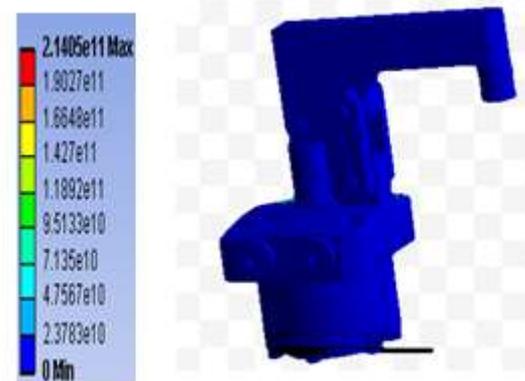


Fig.6: Von-Mises stress distribution for cylinder clamp assembly

Conclusion: The theoretical and FEA clamping force reaction and total force reaction is in well within total and clamping force reaction range. So from all the above results we conclude that value of Clamping forces (Fc) and Total reaction force (FR) by Analytical and ANSYS results are nearly equal with considerably less error value. Therefore, we can further go for finite element analysis of different types of computer aided fixture design models using ANSYS Static workbench so as to get optimized fixture design to be manufactured which is having less deformation and less von-misses stresses.

5. CONCLUSIONS

In this paper, the design requirements of the fixture were studied and according to requirements, modelling was done in modelling software. Verification of the fixture design is carried out using ANSYS workbench. Meanwhile clamping forces are calculated at required optimum hydraulic pressure by using analytical and numerical methods which are validated and are taken into consideration during the static analysis of the fixture and cylinder block, so from FEA result the required type of fixture assembly design is to be considered for manufacturing the final fixture system. Hence, we might conclude that results of values of total

deformations, von-misses stresses and reaction forces from FEA are true. Means the fixture is accurately designed analysed and can be manufactured.

6. REFERENCES

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