Design Modification and Optimization of a CNC Fixture

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***Abstract*- Fixtures are special purpose tools which facilitate as a work-piece holding device that positions the work-piece so that different operation can be performed on it. This paper, design modification and optimization of CNC fixture, is carried for an industrial component. The component is lever shifter situated at bottom of the gear box. The fixture is to be developed for the operation of ball turning of lever shifter. The currently developed fixture is a complicated design with tedious clamping, time consuming and poor locating support. The job machining is on a mass scale. The timing of clamping and unclamping of the work-piece is on an average more than the machining time. The fixture is redesigned in order to reduce the time of clamping and optimize the number of links. The design constraints were studied and the cutting forces were calculated. 3D CAD models were made in CREO and the analysis is done on ANSYS Workbench. Alternative solutions are suggested. The final solution is suggested with the help of comparative results.**

Keywords— CNC fixture, gear box, ball turning, CAD model, CREO, ANSYS Workbench, Clamping, Unclamping.

I. INTRODUCTION

A fixture is a work-holding or support device used in the manufacturing industry. Fixtures are used to securely locate (position in a specific location or orientation) and support the work, ensuring that all parts produced using the fixture will maintain conformity and interchangeability. Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labor by simplifying how work- pieces are mounted, and increasing conformity across a production run. The fixtures must always be designed with economics in mind; the purpose of these devices is to reduce costs, and so they must be designed in such a way that the cost reduction outweighs the cost of implementing the fixture. It is usually better, from an economic standpoint, for a fixture to result in a small cost reduction for a process in constant use, than for a large cost reduction for a process used only occasionally. Each component of a fixture is designed for one of two purposes: location or support.

A. Statement of Problem

The operations performed on the work-piece are broaching, boring and ball turning. The fixture, which is mounted on a CNC machine, Jyoti DX 200, is used to hold this work-piece steady during ball turning operation in a convenient position so that it can be machined. The fixture is so designed that it restricts the twelve degrees of freedom of the work-piece. The time required for clamping and unclamping of job into fixture is about 1 minute on an average. Moreover, this process is tedious as the job needs to be setup in the fixture by fixing 3 links with two different Allen keys, thereby, adding to the complexity of the task. Due to the complexity of the fixture, it becomes an arduous task for a worker to clamp and unclamp the work-piece in the shortest amount of time.

B. Aims and Objective

The objective is to provide a concept of the solution which is applicable to the present scenario as explained. 1) Redesign a fixture which is simple. 2) Redesign a fixture which is easy to clamp and unclamp. 3) Optimize the design by reducing the number of clamping links. 4) Reduce the number of bolts. 5) Reduce time of clamping and unclamping to about 30 seconds. 6) Optimize the clamping process of the fixture. 7) Minimize physical Strain (fatigue) of the worker. 8) Ensure the hardness of the fixture. 9) Ensuring the machining quality is maintained.

II. OVERVIEW

Job Overview

The component 'Lever Shifter' is used in a gear shifting mechanism in the gearbox. The lever shifter is made of the material (EN 10083-2-C35). The lever shifter is a cast product which is sent to Kinetic Gear for machining. The operations performed after casting are as follows 1) Boring 2) Broaching 3) Ball turning 4) Heat Treatment 5) Quality Inspection.

B. Overview of Current Fixture

The current fixture consists mainly of a Base plate, a Mass balancing component, and 3 clamps: Slider clamp, C-clamp, and V- clamp. The clamps are tightened with hexagonal screws. The design is complex the clamping and unclamping process is also cumbersome as each clamp is tightened with a different Allen key. On an average the worker requires about a minute to unclamp and clamp the work-piece which is equal to the machining time. The worker has to keep up with the machining time to complete the task of clamping which induces fatigue.

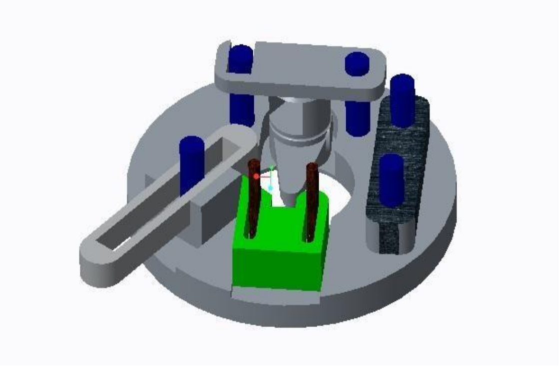

Fig. 1. Current Fixture

III. DESIGNING

A. Design Constraints

1. The Fixture, mounted on the CNC, should be according to the specified size i.e. circular in shape with diameter of 133 mm and thickness of 15 mm.
2. The position of the ball of the work piece should be fixed at the center.
3. The machining process should be unobtrusive. Hence, a circular slot, greater than the work volume of the tool, has to be provided on the base plate of the fixture.
4. If possible, similar bolts are to be used for unlocking and locking of the clamp.
5. Should constrain 12 degrees of freedom.
6. The clamping force must be greater than the cutting force.

B. Proposal of Different Solutions

1. Solution 1

The fixture is designed according to the constraints discussed earlier. The design is made as a CAD model on Creo 3.0. The fixture consists of a sliding clamp, a fixed clamp, a c-clamp and a butterfly bolt. In this proposed solution, one of the clamps is kept fixed while the other one can move in and out. Once the work-piece is loaded onto the base plate, the clamp is slided in, followed by the C-clamp. Both the links are together fixed with a single Allen Key. All constraints are followed and according to the cutting force analysis the design is safe.

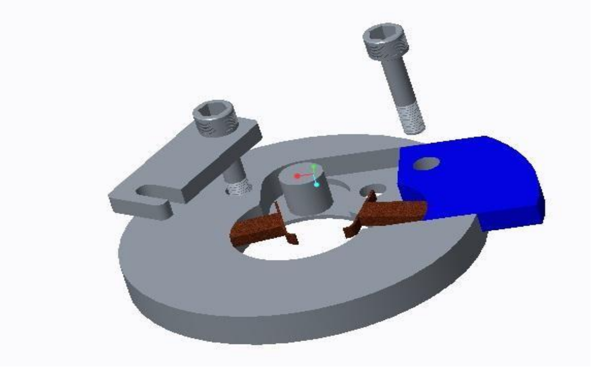

Fig. 2. Proposed Solution 1- without work-piece

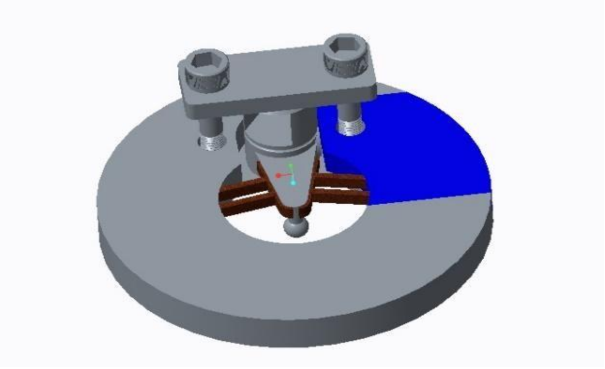

Fig. 3. . Proposed Solution 1- with work-piece clamped

2. *Solution 2*

The fixture consists of a single V-clamp, which is modified to cap the work-piece and 2 hexagonal keys. The modified V-clamp is shown in the figure. However, butterfly bolts have also been suggested as a replacement of the hexagonal screws.

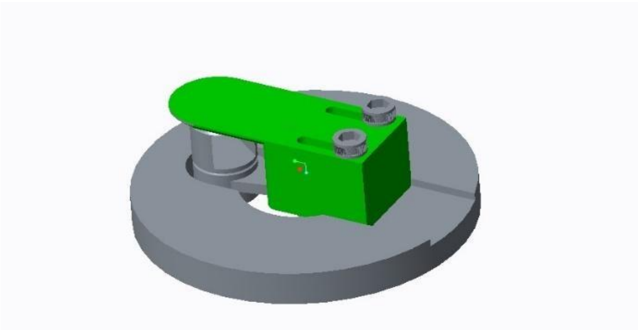

Fig. 4. Proposed Solution 2- with work-piece clamped

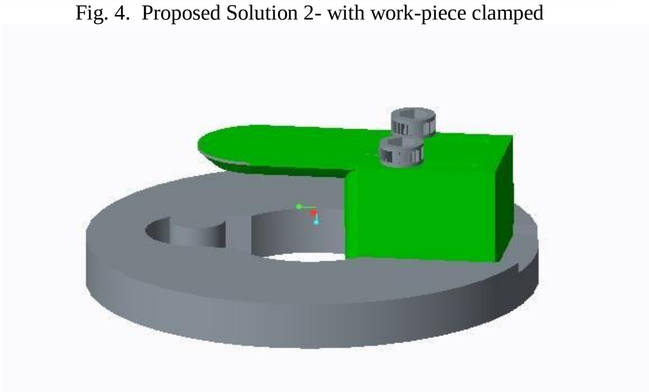

Fig. 5. Proposed Solution 2- without work-piece

3. Solution 3

The fixture consists of a slider which is fixed on the other end of the work-piece as compared to the original design. The slider clamp slides into the work-piece at 30^0 from vertical into the broached part of the work piece. A butterfly bolt is proposed for fixing it to further reduce the time and efforts. It also consists of a link loaded with spring to aid the locating of the work-

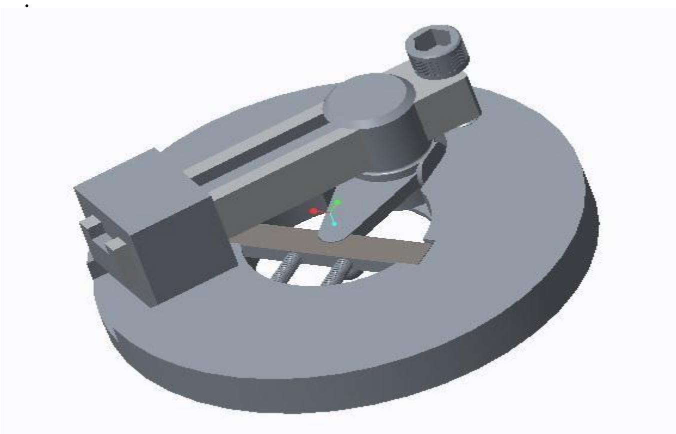

Fig. 6. Proposed Solution 3- with work-piece clamped

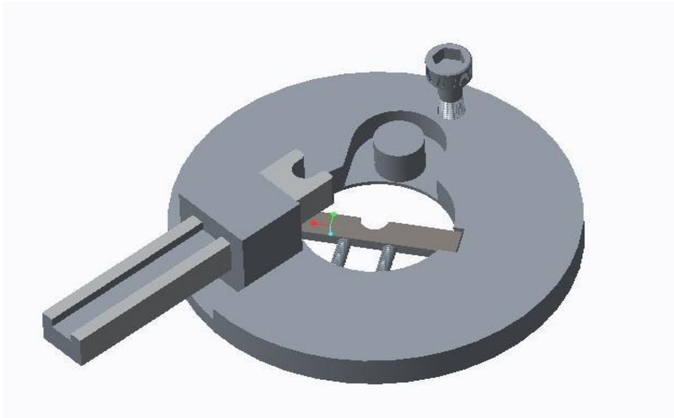

Fig. 7. Proposed Solution 3- without work-piece

IV. ANALYSIS

The static Analysis is done on ANSYS 15 Workbench. Mesh type: Coarser. Isometric element: tetrahedron. The base plate is fixed and the cutting force is applied on the ball profile where the turning operation is to be performed. The Fig. 8. shown below shows that the force applied is 400 N, which is greater than the actual cutting force pertaining to the factor of safety. The analysis is obtained for the total deformation, equivalent strain and equivalent stress.

The Fatigue Analysis is done on ANSYS 15 Workbench. Mesh type: coarser. Isometric element: tetrahedron. The fatigue is repetitive application of physical quantities to find out the life cycle and the factor of safety. Here the base plate is in motion at 120 rad/sec in z axis and 320N load is applied as a cutting force load in –z direction. The above representation is the life cycle analysis of the fixture. The below representation is the safety factor analysis. The life of the fixture is determined as 1e+9 cycles.

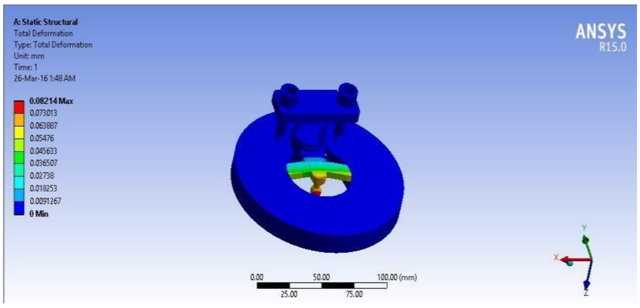

Fig. 8. Static Structural Analysis of Solution 1(a)

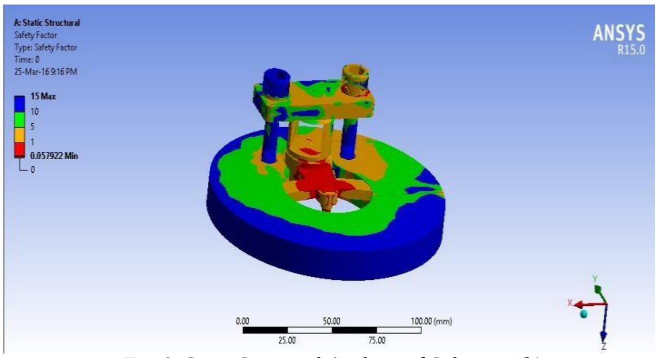

Fig. 9. Static Structural Analysis of Solution 1(b)

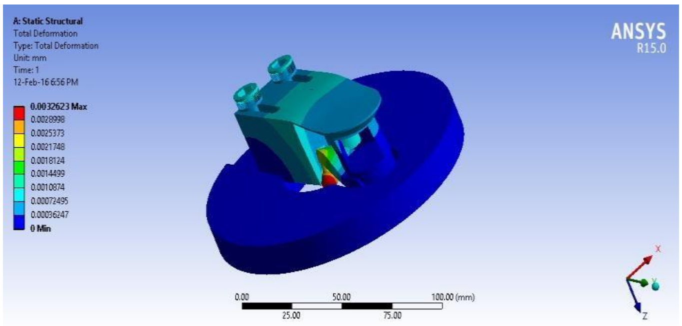

Fig. 10. Static Structural Analysis of Solution 2(a)

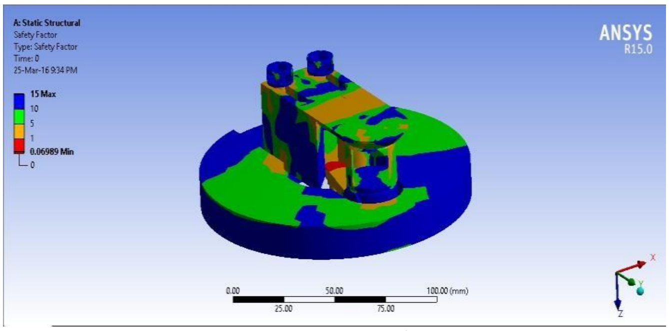

Fig. 11. Static Structural Analysis of Solution 2(b)

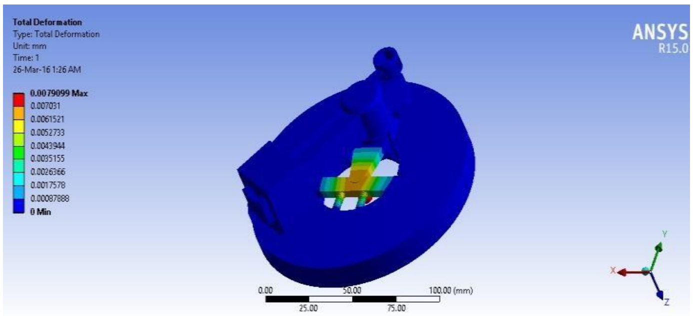

Fig. 12. Static Structural Analysis of Solution 3(a)

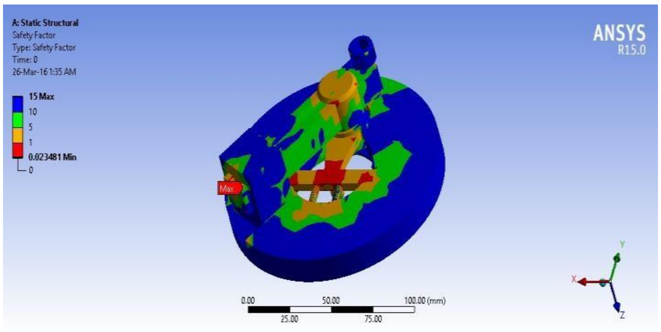

Fig. 13. Static Structural Analysis of Solution 3(b)

V. COMPARATIVE STUDY

TABLE I

	Design 1	**Design 2**	**Design 3**
Mass in kg	1.59	1.74	1.89
Total Deformation in mm	0.08214mm	0.0032623 mm	0.007909mm
Equivalent stress MPa	Min 2.4973e-11 MPa. Max 147.06 MPa	Min 1.1272e-8 MPa. Max 46.588 MPa	Max 97.07 MPa
Equivalent strain mm/mm	Min 1.937e-16 Max 000858 mm/mm	Min 1.3801e-13 Max 0.00027085 mm/mm	Max 0.00049969
Damage Factor	Max 1.13e+007	Max 7.1333e+007	Max 8.4284e+007
Safety Factor	Min 5.7922e-002	Min 6.989e-002	Min 2.3481e-002
Life cycles	1e+9 cycles	1e+9 cycles	1e+9 cycles

VI. SELECTION OF DESIGN

A. Design-1 fails in clamping action. The slider marked in blue color will not able to hold the job due to the cutting force and speed of rotation. As well as its analysis shows deformation 0.08mm due to cutting forces greater than the other two designs. Hence, design-1 fails or is rejected.

B. Design-2, after several cycles, will show failure in the clamper due to repeated clamping. The protruded flange element will gain a specific shape which would not be able to clamp the job precisely and cutting forces exerted on that particular element are shown in analysis.

C. Design-3 satisfies all the clamping criteria as well as the deformation, due to the forces exerted is relatively lesser. Hence, the Design-3 clamps the job precisely and reduces the clamping and unclamping time.

VII. CUTTING FORCE CALCULATIONS

A. Parameters

1. Spindle Speed= 3000 rpm
2. Depth of cut= 0.75 mm
3. Feed rate= 0.06 mm/rev
4. Cutting speed (Vc)= 43.46 m/min
5. Length of cut= 15.5 mm
6. Diameter of ball= 11.5 mm
7. Tangential Force/Cutting Force (Fc)= 31.122N
8. Feed Force (Ff)= -62.92N
9. Radial Force (Fr)= 146.51N

VIII. FINAL SOLUTION

According to the comparative studies, Solution 3 will be the final proposed solution. The assembly is presented above (Fig. 6.). The components are modified base plate, modified slider clamper, a hexagonal Screw and a support strip attached to the base.

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