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Design and Numerical Studies on Clamping Fixture for Machining an Automotive Pump Body

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Abstract—the paper discusses the design and analysis of a clamping fixture for a vertical machining centre (VMC) to machine an automotive pump body. Recent increase in competition, many industries has revisited their strategy to improve productivity. New and innovative ideas have to be implemented in the production sector to achieve the superior product. In particular, the recent development in the design field made to target towards increasing the accuracy of finished part and decreasing the production time and cost. An attempt has been made to design clamping fixture on a vertical machining centre which can produce holes and milled side faces on a component accurately, at a faster rate to improve the productivity. Various components and their dimensions are fixed based on theoretical design. Subsequently considering standards, and catalogues, production ready drawings models are prepared using AutoCAD, SOLIDWORKS, and FEM analysis is carried out by ANSYS for the fixture design.
Key Words: Clamping Fixture, Automotive Pump Body, VMC, AutoCAD, SOLIDWORKS, ANSYS.

I. INTRODUCTION

Many researchers have attempted to design a suitable fixture based on requirement for certain applications. The designed fixture must be fit for situating, holding and supporting work piece during machining. The installation ought to minimize work piece uprooting amid machining. An installation work piece framework is liable to two primary strengths: clasping powers and cutting powers. Proper fixture design is very crucial for exactness, precision and completion of the machined part as reported by Kaya and Ozturk [1]. Lee and Haynes [2] suggested that the high push may bring disappointment of the work piece. The vast distortion may bring the loss of exactness in accuracy machining. The machining strengths are indicated as the connected powers on to the machining face of the segment. Understanding the loading conditions, type and properties of materials, proper design tools for modeling are few more points to be considered in the design and fabrications of fixture. From the literature it is summarized that the proper knowledge and idea is required to design, analyze and install the fixture for machining a component. With this, the objective of the paper is to discuss in detail design and analysis using ANSYS. Moreover, the overall intention is to improve the productivity rate, minimize the time, and simple design.

II. AUTOMOTIVE PUMP BODY

The machining of an automotive pump body comprises two operations. Side milling operation on both sides and drilling four holes on a component are the two operations. These operations will be carried out using manual clamping procedure, due to which it seems to be complex and other drawbacks such as increase in cycle time, decrease in production rate and poor accuracy in the output component. Henceforth, the objective of the present work is to overcome the disadvantages with suitable fixture design that will facilitate both milling and drilling operations on single vertical machining center in single stroke. This will help to achieve high production rate, reduced cycle time, and reduced labor, and increases accuracy and precision of the product. The tool specifications are listed in Table 2.1.

Table-2.1 Tool Specification

Tool	Fixture
Type of fixture	Clamping Fixture
Operating mode	CNC
Type of clamping	Hydraulic Clamping
Loading of Component	Two at a time

The different components in a proposed clamping fixture design are base plate, L-bracket, moving and fixed V-block. The base plate is placed on L-bracket that will facilitate to install moving and fixed V-block, and specimens. The L-bracket will be fixed to both head stock and tail stock using right handed rotary table that rotates the base plate at 90^o to perform the specified operations i.e. to mill the other side of the pump body. The moving V-block will be placed over the base plate and is used to proper positioning, clamping, loading and unloading the specimens. The fixed V-block will be placed over the base plate and is fixed. This will facilitate to place and clamp the two specimens at a time and to perform specified operations. The components of the proposed clamping fixture are listed in Table 2.2.

Table-2.2 Components of Clamping Fixture

Sl.no	NAME	Quantity
1	Base Plate	1
2	L-Bracket	2
3	Moving V Block	2
4	Fixed V Block	1

III. MATHEMATICAL MODEL OF CLAMPING FIXTURE

The proposed clamping fixture model is built in a solid works environment based on design specifications. Stainless steel is material chosen in building the clamping fixture. The schematic layout of a clamping fixture is shown in Figure 3.1.

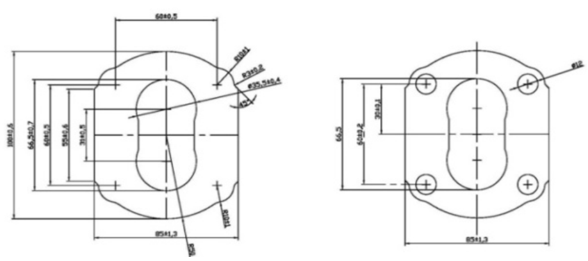

Fig -3.1: Schematic layout of a clamping fixture.

The model is built using SOLID WORKS and is shown in Figure 3. 2. ANSYS package is used to solve the built up model. The three basic finite element analyses are pre-processing, processing and post-processing.

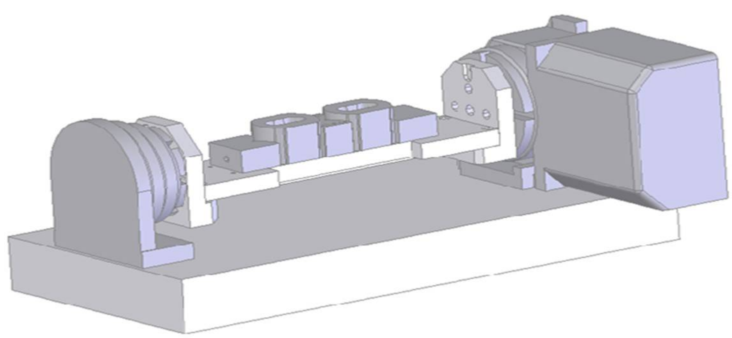

Fig -3.2: Model of Clamping Fixture

IV. MESHED MODEL OF CLAMPING FIXTURE

The model is imported in a ANSYS environment and meshing is done. Solid mesh is generated considering 10 mm mesh size. The meshed model is shown in Figure 4.1 and the meshed parameters are listed in Table 4.1. Discretization is carried out with a mesh hybrid combination of tetrahedral and hexahedral elements.

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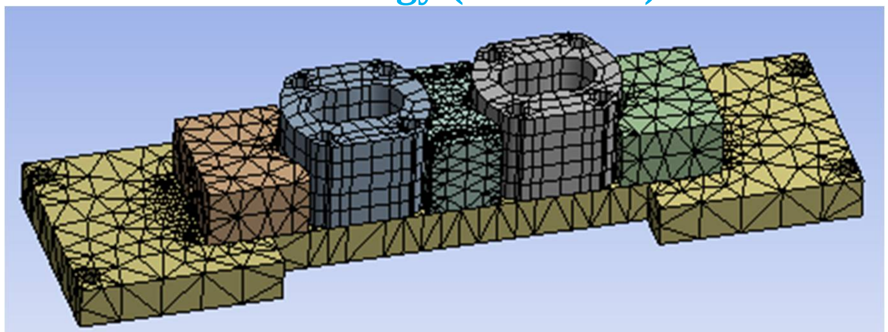

Fig -4.1: Meshed model of Clamping Fixture.

Table-4.1: Mesh Parameters

Element	3D 4-Noded Tetrahedral, 3D 8-Noded Hexahedral
Element Sixe	10 mm
Min. Edge Length	6 mm
Total no. of Nodes	63774
Total no. of Elements	35163

V. BOUNDARY AND LOADING CONDITIONS

Deck preparation is carried out by applying the loads at appropriate locations. The tangential cutting force of 506N is applied constraining the geometry at the fixed locations using Fixed Support Constraint. The prepared model loaded with pressure and constrained with fixed supports that is ready for the analysis is shown in Figure 5.1 The mechanical properties of stainless steel are tabulated in Table 5.1 Considering the factor of safety equal to 3, analytically the allowable stress in the material is 68.33 N/mm^2.

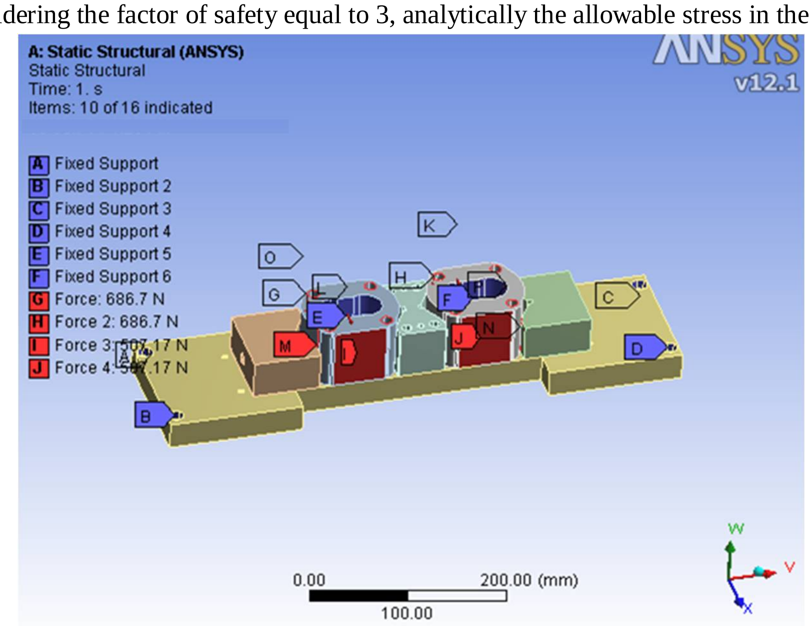

Fig -5.1: Boundary and Loading Conditions imposed on Clamping Fixture

Table -5.1: Mechanical properties of Stainless Steel

Tensile Strength (MPa)	215 to 505
Yield Stress (MPa)	205
Density (Kg/m^3)	8000
Poisson's Ratio	0.29

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VI. STATIC ANALYSIS

Displacement and stress induced will be verified using static structural non-linear analysis. Clamping fixture is processed using SOLID WORKS and further solved using ANSYS. The stress concentration and displacement of a clamping fixture is evaluated. Figure 6.1 shows the contour plot of total deformation of a clamping fixture. Maximum deformation of 0.0023569 mm has been observed. Figure 6.2, 6.3 and 6.4 shows the contour plots for displacement obtained along the x, y and z directions respectively. It has been observed that the maximum deformation is decreasing along the three directions. Maximum deformations achieved are 0.0023073, 0.00043629 and 0.00074273 mm along x, y and z directions respectively. Further, the maximum deformations of a clamping fixture are listed in Table 6.1.

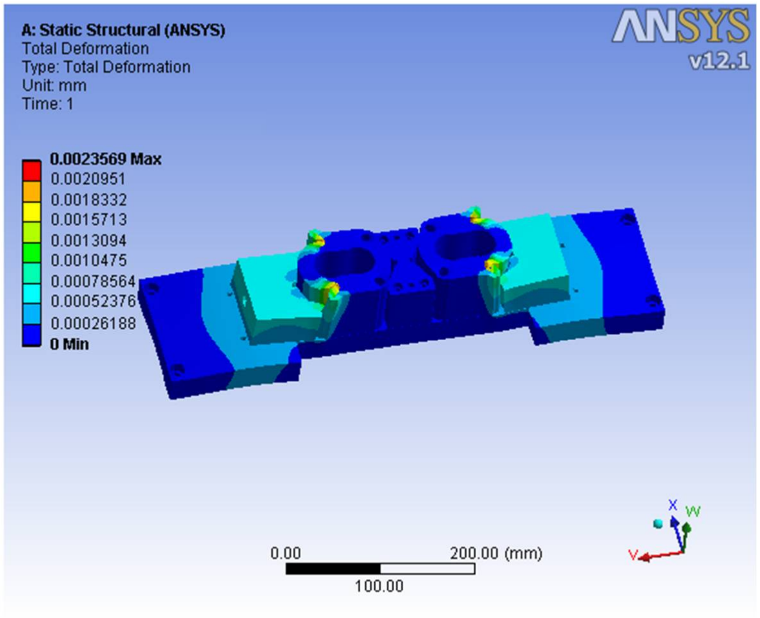

Fig- 6.1: Contour plot of total deformation in mm

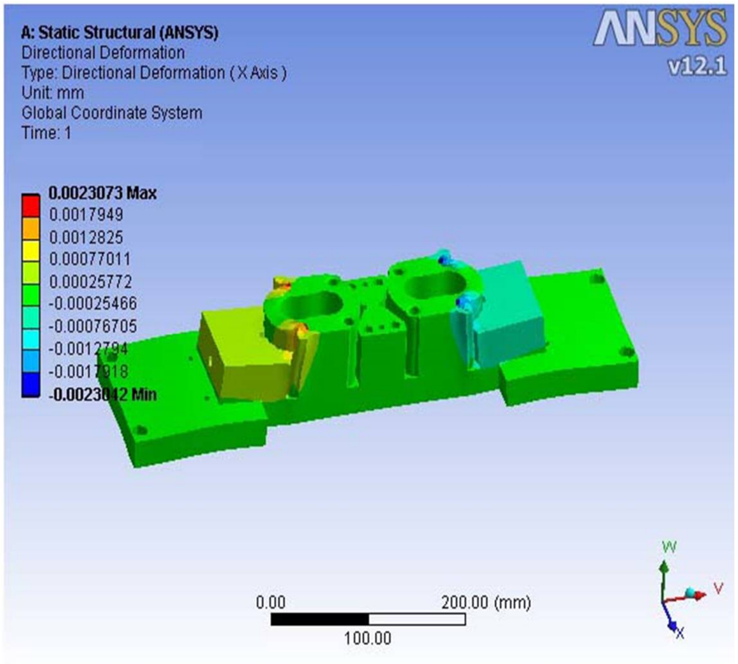

Fig-6.2: Contour plot of directional deformation (x-axis) in mm

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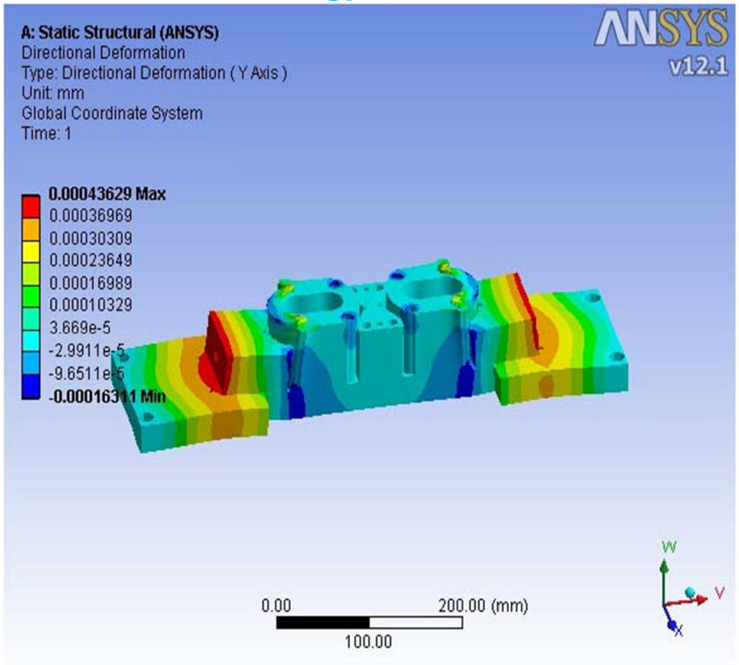

Fig-6.3: Contour plot of directional deformation (y-axis) in mm

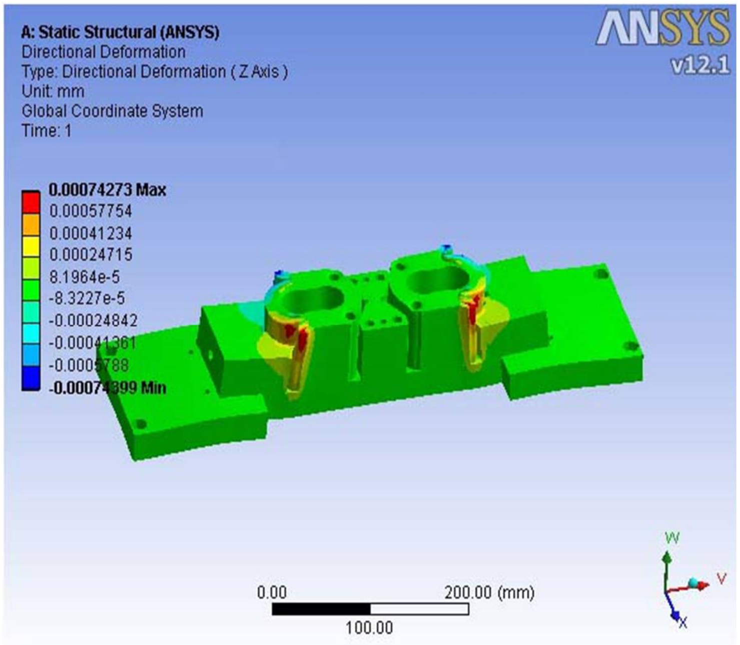

Fig-6.4: Contour plot of directional deformation (z-axis) in mm.

Table-6.1: Maximum deformation of clamping fixture

Total deformation	(mm)	0.0023569
Deformation(x-axis)	(mm)	0.0023073
Deformation (y-axis)	(mm)	0.0004362
Deformation (z-axis)	(mm)	0.0007427

Figure 6.5 shows the Vonmises stress induced in a clamping fixture. It has been observed that the maximum stress of 33.749 MPa is induced in a clamping fixture.

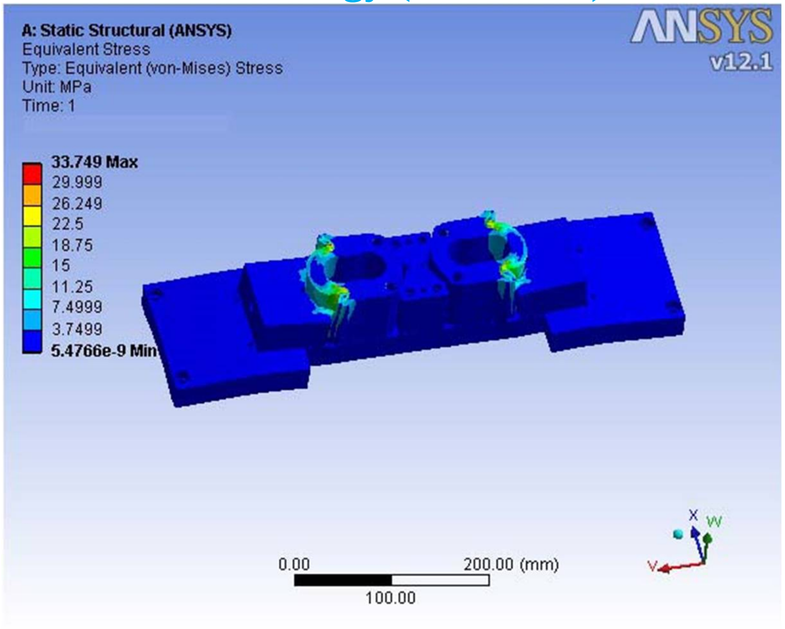

Fig-6.5: Contour plot of Vonmises Stress in MPa

Table 6.2 shows the comparison of analytical and FEM Vonmises stress induced in the material of the clamping fixture. It has been observed that the deviation of 51 % is found in Vonmises stress on comparing finite element result with analytical result.

Table-6.2: Comparison of Vonmises stress

Results	Stress in MPa
Allowable stress	68.33
FEA results	33.7

VII. CONCLUSION

The paper discussed the outline of design and analysis to minimize the cycle time and labor in order to increase the rate of production. Newly developed clamping fixture with new design the cycle time minimizes to around 20 to 30 %. This in turn increased the production rate.

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