DESIGN AND ANALYSIS OF FIXTURE FOR BANJO BEAM ON CNC TWO WAY HORIZONTAL MACHINING CENTRE

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Abstract: Machining of heavy mechanical components needs a rigid fixture; a banjo beam is one such component which is an enclosure for rear case axle of automobile with more than three wheels. Various machining operations like milling, boring and drilling is performed to obtain the protective shape of banjo beam. Banjo beams having different lengths for different platforms of vehicles are being fabricated using CNC Special purpose machines. This paper aims for effective design of fixtures to accommodate workpiece of various lengths, minimizing the stress sourced from the clamping and cutting forces originated during the machining operation of two ways Horizontal Machining Centre (HMC). A comparison of various types of fixtures and forces of machining along with the different lengths of work pieces is taken into consideration to arrive at a final detailed design. The results of detailed design are simulated with the preparation of 3D models of different parts of fixture assembly with the aid of Solid Works software. The validation of the final design is performed by subjecting the complete assembly with banjo beam to the real-time boundary conditions using finite element analysis using ANSYS Software.

***Index Terms* -** Banjo beam, Fixtures, Special purpose machine, Horizontal Machining Centre (HMC), Solid works and Ansys.

i INTRODUCTION

Fixture is widely used to locate and support the workpiece in various industries. The most important functions of a machining fixture are to locate, constrain, and effectively support the workpiece amid machining. These capacities are accomplished by tactically placing orientation pins, clamps, and supports around the workpiece and applying the proper clamping forces (5). A poor preference of the positions of the fixture elements and clamping force(s) is capable of showing the way to undesirable workpiece deformation and low dimensional/form precision of the workpiece. Thus, a vital contemplation in fixture design is to optimize the fixture layout i.e. positions of locators and clamps, so that workpiece deformation due to clamping and machining forces is minimized (4). The capacities of a machine tool are anticipated in terms of cost efficiency, throughput, reliability and quality (1). In a horizontal machining center the spindle axis is in horizontal direction. Because of high accuracy and flexible outcomes of hydraulic systems, the tendency to use the hydraulic techniques in any mechanical systems is more (11). The Robust combination of hydraulic force and the good fixture design yields accurate machining results. Machining operations like milling, boring and drilling is done on banjo beam having different length in CNC Special purpose two ways Horizontal Machining Centre (HMC). So a machining fixture is designed to hold the component of different length by providing T-Slots on fixture base. This paper focuses on selection of suitable hydraulic link clamps and hydraulic cylinders for holding and locating the component. Fixture reduces process time, increases efficiency and best excellence of process is achievable. Project deals with the design of different parts of fixture assembly, 3D modeling by using Solid Works and finite element analysis of banjo beam by using ANSYS software.

ii Design of T-slots for Fixture Base

“T-slots” are accessible on the majority of machine tool tables for clamping purpose. A T-slot be able to be decayed into two disconnect features, a slot and a groove. The vital characteristics of a T-slot are throat width and depth, headspace width and depth and their individual tolerances (AR Darvishi). These qualities jointly with the distinguishing traits are incorporated in the data structure given away in Figure. T-Slot nuts, which are utilized in work holding in machine tools. T Slot nuts fit in T-section slots in the machine work table. From this reference T-Slot is given in fixture base to hold the some fixture elements.

Standard T-Slot dimensions are taken from ANSI standard (Machinery’s hand book 29th edition) Standard T slots is taken so it is not necessary to validate and it is implemented on the fixture base.

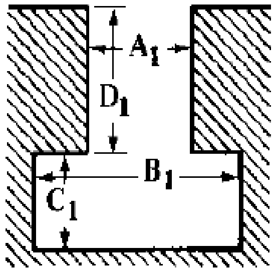

Figure 1: Basic dimensions of T slot

Throat Width (A_1) = 14mm
Headspace Width (B_1) = 23mm
Headspace Depth (C_1) = 9mm
Throat Depth (D_1) = 12mm

Throat dimensions are basic. At the point when slots are intended to be utilized for holding only, tolerances can be 0.0 + 0.010 inch or H12 Metric (ISO/R286).

iii Design calculation for clamping force

Some data are taken from machine specifications:
Component material – Forged steel
Hardness – 149 to 187 HB
Diameter of cutter (D) – 106mm
Revolutions per minute (n) – 450
Depth of cut (t) – 3mm
Width of cut (b) – 10mm
Feed per tooth (Sz) – 0.16mm

1. Cutting speed
   v = π x D x n/1000 = 149.8257m/min
2. Feed per minute
   S_m = Sz x Z x n = 288mm/min
3. Metal removal rate
   Q = b x t x S_m /1000 =31.104cm^3/min
4. Approach angle
   Assume approach angle x = 90deg
5. Average chip thickness
   as =57.3 x Sz x SinX(CosΨ1°-CosΨ2°)/Ψs°=0.031062716mm
6. Unit power
   U = 0.09kW/cm^3/min (CMTI data book, table 269)
7. Correction factor for flank wear
   K_h = 1.18 (CMTI data book, table 270)
8. Radial rack angle
   ϒ = 5deg (From CMTI data book)
9. Correction factor for radial rack angle
   $K_ϒ$ = 1.07
10. Power at the spindle
    N = U x K_h x $K_ϒ$ x Q = 3.534471936kW
11. Efficiency of transmission
    E = 90%
12. Power of motor
    N_{el} = N/E = 3.92719104kW
13. Tangential Cutting Force
    P_z = 6120 x N/v = 1414.86N
14. Torque at Spindle
    T_s = 975 x N/n = 7.658022528kgf

According to the above calculation it is discovered that the tangential cutting force is 1414.86N. The clamping force must be more than the cutting force so we are taking the clamping force three times the tangential force. To provide an adequate margin of safety for the clamping system, this value should be increased [12].

Clamping force = 3 x tangential cutting force
Clamping force = 3 x 1414.86 = 4244.58N

Then the clamping force required for clamp the component is 4244.58N. Therefore select the clamping device which having 4.248KN clamping force.

iv Fixture assembly

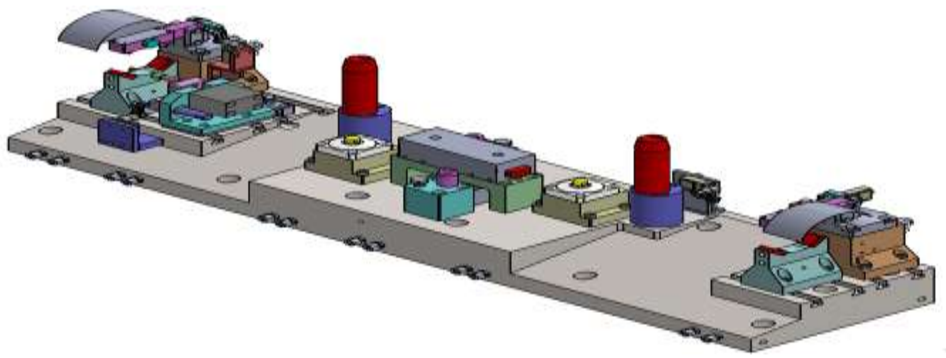

Figure 2: Fixture without component

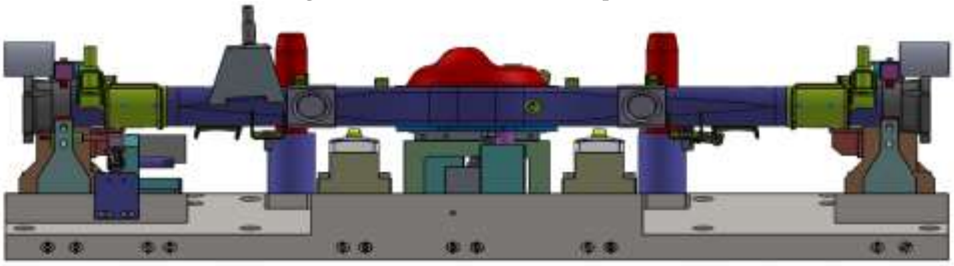

Figure 3: Fixture with component

Component length setting

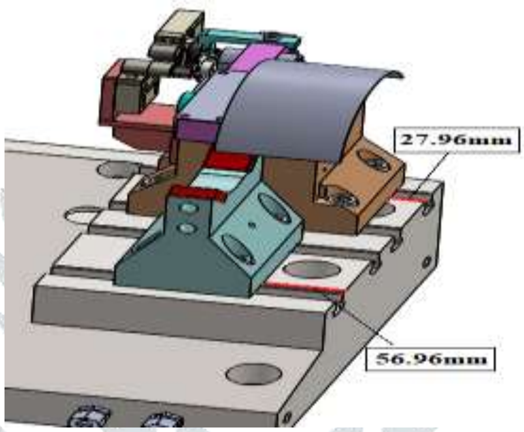

Figure 4: Component length setting

v FINITE ELEMENT ANALYSIS

In this study workpiece is considered as forged steel material. Prior the stage of scrutiny, it is essential to identify the location where the clamp should be placed and characterize pre-processor prerequisites such as element type, material properties, and boundary conditions so on. Ansys software (18.1) is used for analyze the deformation of component.

Importing model: The 3D models of component A and component B are imported in .igs file format
Meshing: The meshing is done with the mesh size of 4 mm and other parametric values like shape of mesh, aspect ratio of elements, mesh control, tolerance, etc. are considered.

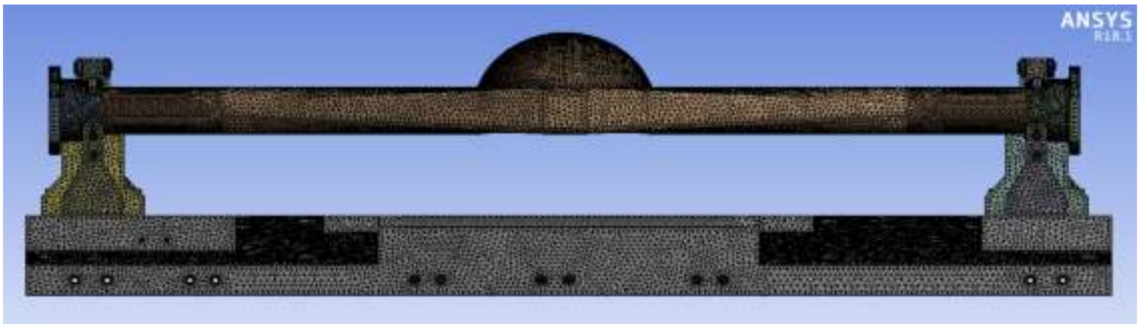

Figure 5: Mesh Model

Table 1: Analysis Parameters

Parameters	Component A	Component B
Type of Analysis	Static structural	Static structural
Type of co ordinate system	Global co ordinate system	Global co ordinate system
Type of meshing	Tetrahedral element meshing	Tetrahedral element meshing
Type of contacts	Bonded	Bonded
Number of elements	947607	759076
Number of Nodes	1626666	1307269

Table 2: Material properties

Parameters	Plain carbon steel
Tensile strength	570-700Mpa
Hardness BHN	170-210
Elastic modulus	190Gpa
Poisons ratio	0.293
% of elongation	40
Compressive Strength	256Mpa
% of Carbon	0.3

Static Structural Analysis Setting

The cutting force acting on the workpiece is used as machining force and hence clamping force is taken as a point load in FEA. Then Finite Element Analysis is to be carried out on the work piece. Bottom of the fixture base is fixed as shown in the below figure. Clamping Force is acting in downwards in 'Y' direction of 3200N and moment of 40N-m in clock wise direction is applied on both side of the component as shown in the figure.

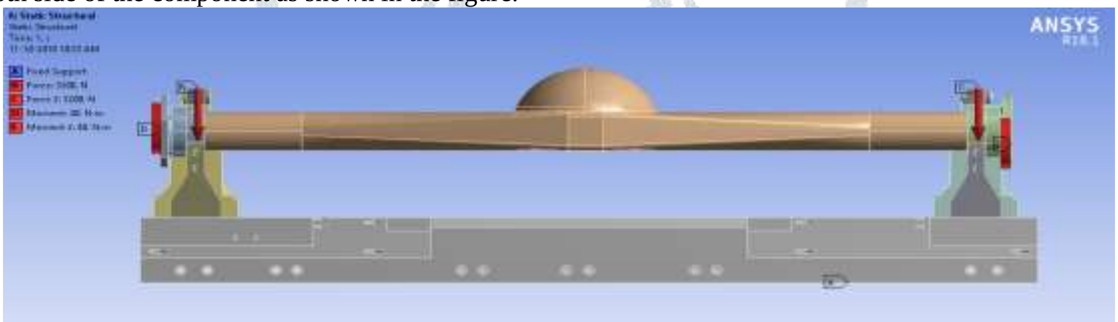

Figure 6: Loading conditions of component

vi RESULTS AND DISCUSSION

Total Deformation

Figure below shows the maximum deformation of component A having maximum value of 6.7961e-6m and component B having maximum value of 7.7185e-6m.

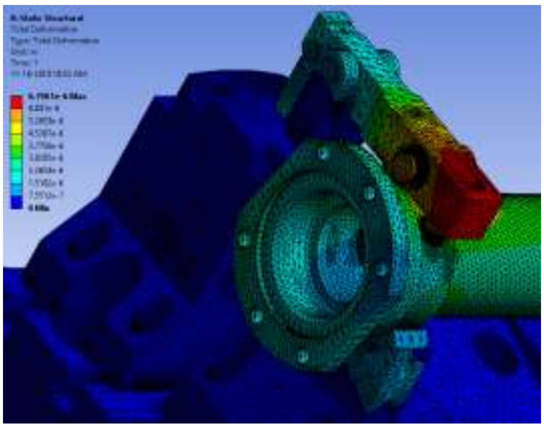

Figure 7: Deformation of component A

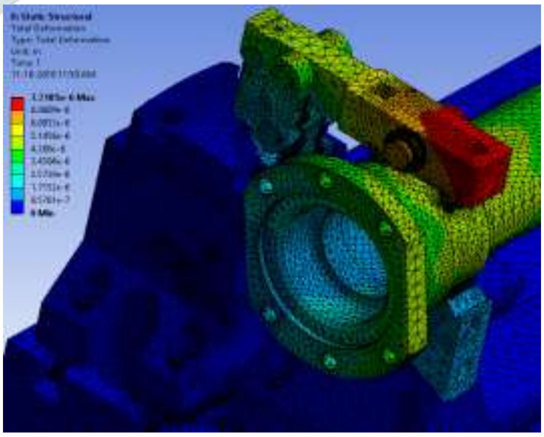

Figure 8: Deformation of component B

In the analysis of component A and component B it is found that the maximum deformation at clamp lever is 6.7961e-6 m and 7.7185e-6m respectively.

Von mises stress analysis

Figure below shows the Von mises stress for component A and component B having maximum value of 1.3793e8Pa and minimum value of 5.249e-5Pa.
Figure below shows the Von mises stress for component B having maximum value of 1.6356e8 Pa and minimum value of 0.0001923 Pa.

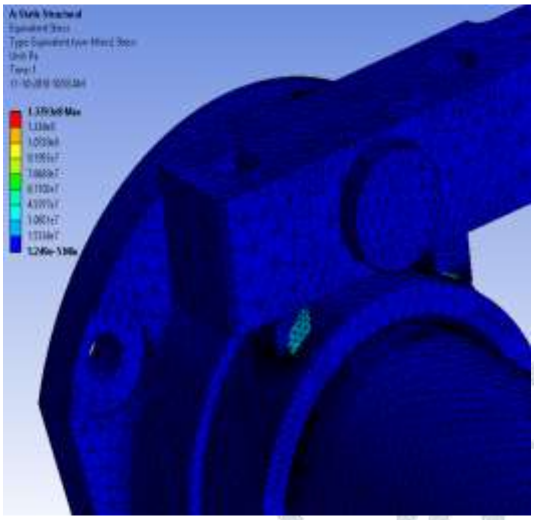

Figure 9: Von mises stress for component A

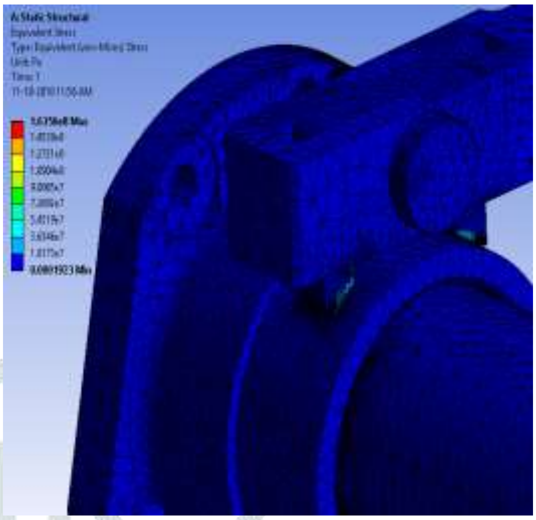

Figure 10: Von mises stress for component B

The above results of component A depicts that the value of Von mises stress is between 1.3793e8Pa and 5.249e-5Pa which is within the range of 4.15e8Pa. These values are within the safe limit for the forged steel material. And similarly the results of component B depicts that the value of Von mises stress is between 1.6356e8Pa and 0.0001923Pa which is within the range of 4.15e8. These values are within the safe limit for the forged steel material (table no 2).

Convergence Results

Convergence criteria are the path followed by the solution to eliminate non linearity's in the solution. In Ansys there are four convergence criteria (force, displacement, moment and rotation). A convergence test is always needed to be conducted to determine the size of elements in finite element modeling. Convergence is all about conservation of energy and the difference between the input energy and the work done. By default Ansys is using Newton Raphoson method for predicting the results t each iteration and whether the result is converged or not.
For the current convergence criteria, 30% of allowable change for 4 refinement loops and one refinement depth are given to obtain the convergence results for both component A and component B.

Convergence result for component A and component B

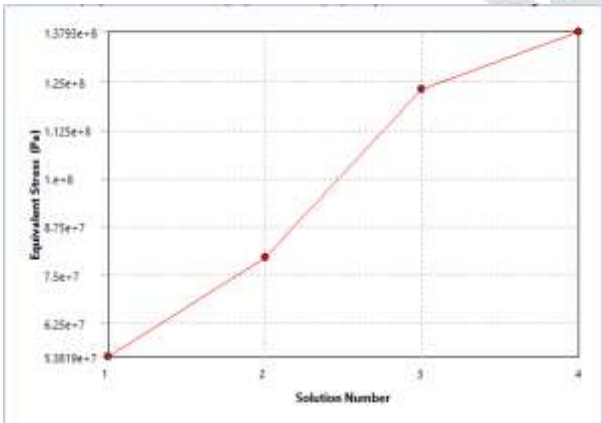

Figure 11: Graph of convergence result for component A

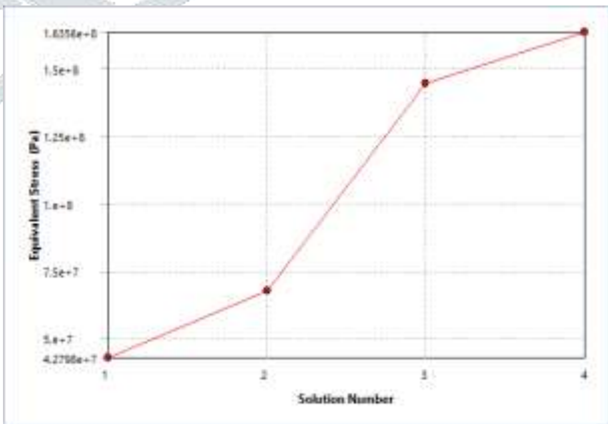

Figure 12: Graph of convergence result for component B

The above characteristic curve depicts that the equivalent stress of both the cases viz component A and component B is converging to a magnitude of approximately 140 MPa at the set iteration of 4 and deviation of 12%.

vii CONCLUSIONS

Banjo beam fixture was designed and analyzed using ANSYS software. It is designed to increase the productivity.
The following conclusions could be drawn from this study:

1. The existing fixture set up was designed only for same length component, was replaced with varying length of component.
2. The proposed fixture won't only gives the repeatability and high profitability, yet in addition offers a solution, which reduces workpiece distortion due to clamping and machining forces.
3. Structural analysis of the fixture shows the maximum deformation to be 6.7961e-6m and 7.7185e-6m for both component A and component B. These values are within the safe limit for the forged steel material.
4. Convergence study of equivalent stress of component A and component B reveals that the value of von mises stress are 137.93MPa and 163.56MPa

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