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Design And Analysis Of Machining (Hydraulic) Fixture For AVTEC Transmission Case Component

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Abstract— **In order to have interchangeable parts in mass production, jigs and fixtures play a vital role in manufacturing process. A fixture is a special tool designed for specific purpose and for specific component for operation. The present work deals with the design of machining fixture for milling and drilling operations for a crank case. The cutting forces involved in the operations are taken into consideration for designing the fixture.**

The present fixture designed is hydraulic operated and used for operation like face milling, drilling, Tapping, Rough &Finish Boring of the crank case. Design standards are taken from Makino for designing this machining fixture. 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.

Since the final component cannot be produced by a single operation it is necessary to plan for various operations to get the final shape. The fixture is then designed by considering all the clamping forces from various cutting operations.

Keywords – jigs, fixture, Design,Ansys, **etc**

I. INTRODUCTION

Fixtures are devices which are designed to repeatedly and consistently maintain the orientation of a work piece during machining, assembling, welding, inspection etc. They are an essential part of manufacturing. Fixtures are used to locate the work quickly and accurate support it properly and hold it securely, thereby ensuring that all parts. Produced in the fixture will come out alike within the specified limits, in this Way accuracy and interchangeability of the parts are provided.

INTRODUCTION TO FIXTURES

Fixture is a special tool used for locating and firmly holding a workspace in the proper position during a manufacturing operation. As a general rule it is provided with devices for supporting and clamping the work piece. It is fixed to the machine bed by clamping in such a position that the work in the correct relationship to the machine tool elements.

These are the devices, which accelerate the production particularly with 100% interchangeable parts. The origin of fixtures can be traced back to the Swiss watch and Clock industry from which after proving their usefulness they spread throughout the metal working industry.

Inside of machine shop Jigs and Fixtures are used for the following operations: Boring, Broaching, Drilling, Grinding, Honing, Lapping, Milling, Planning, Profiling, Reaming, Sawing, Shaping, Slotting, Spot facing, Tapping and Turning. Outside of the machine shop, fixtures may be applied to advantage for: Assembly, Brazing, Heat treating, Inspecting, Riveting, Soldering, Testing and welding

Transmission Case

Transmission Case used in this project to design a machining fixture is used in automobile vehicles. Transmission 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. Four dowel holes are present in the transmission case. Two dowels are used for assembling of front and rear housing to make it a unit and other two dowels are used for locating the transmission case in the fixture. Locating pins are used to accommodate the variation in the centre distance during machining.

II Problem statement

To Design a machining fixture and analyze the stress distribution and displacement variation on the fixture for Transmission case used for housing of automobiles transmission. Transmission case is shown in fig.

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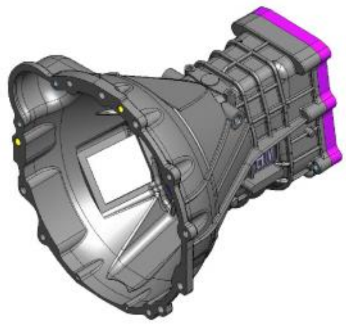

Fig-1

The above fig shows the transmission case for which a machining fixture is to be designed to perform the different type of operations i.e. boring, milling, taps, drilling etc.

Component details:

- Material – Aluminum
- Weight of the raw casting =11.22Kg
- Weight of the finished component =10.15Kg
- Operations to be performed on Crankcase are (1) Drilling (2) Reaming (3) Tapping (4) End milling (5) Boring

Fixture details:

- Type: Hydraulic
- Clamping force: 19.55 KN

Component Machining Details

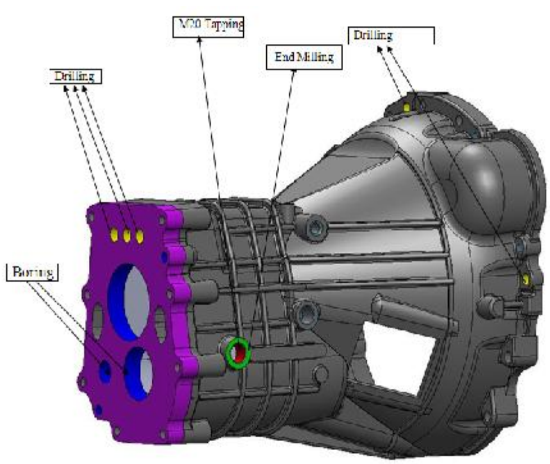

Fig-2

REQUIRED DATA TO DESIGN THE FIXTURE:

S.NO	REQUIRED DATA	WHY REQUIRED?
1	Component Details: Drawing (pre-machined & machined) Operations to be performed. Input condition of the component. Casting Forging Pre-Machined 3-D model of component. Material. Co-efficient of friction of material. Strength Poisons ratio Hardness	To decide Locating surface Clamping surface Resting surface To calculate Clamping force. To do FEM analysis.
2	Process Related Details Type of operation Spindle speed Feed Depth of cut (doc) Width of cut	To calculate Cutting force
3	Cutting tools Details Tool dimension Tool geometry Tool material	To calculate cutting force To check interference With any fixture parts. To check reach of the tool to machining area of the component.
4	Machining Details Max. movement of spindle Machine bed details Indexer detail	To check interference with any fixture parts To mount the fixture on mac
5	Demand Capacity	To decide type of clamping manual or power clamping.
6	Process capability details	To decide accuracy of fixture Rigidity of the fixture
7	Cost Investment	To decide type of clam manual or power clamping.
8	Different variety of the component to ru the same machine.	To consider set-up change over

Fixture assembly with Component

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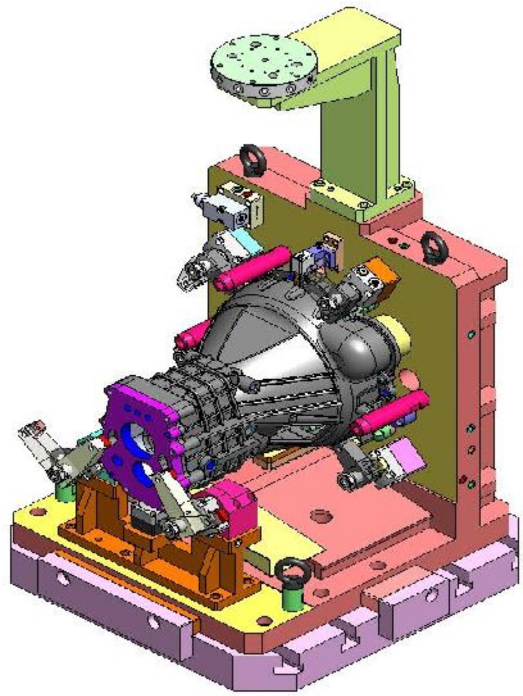


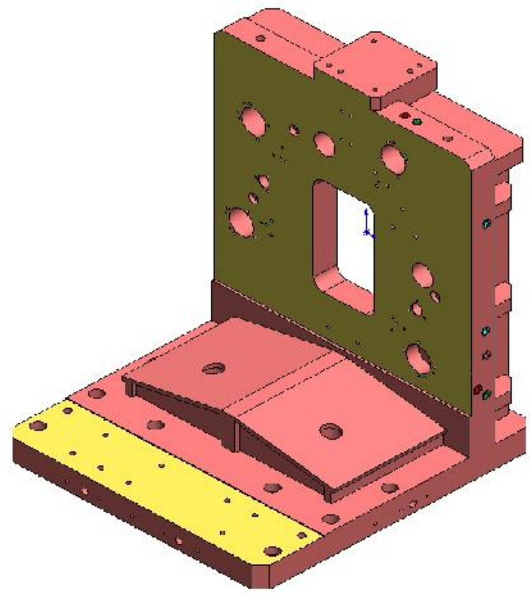
Fig-3

Fixture Elements:

1. **Base structure (weldment)**

It is made by Mild steel (Alloy steel). It is rigid and can withstand high vibrations. This structure is designed & modeled by depending upon the customer requirement. The main requirement of the customer is to reduce the chip accumulations. Similarly, the weight of the structure is also considered because the machine can bear limited weight (check machine specifications).

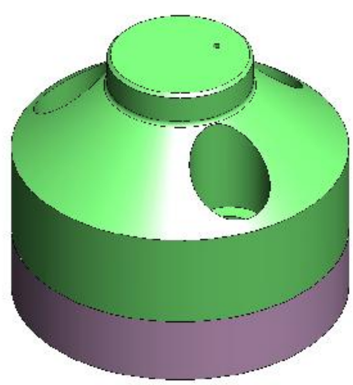
The size of the structure is considered depending upon spindle working area, tool changing area and finally total swing area of pallet in the machine. Here the weldment structure is provided with machining allowances for required machining area .And also considered parts fixing holes and hydraulic piping holes on base structure Before going to provide Hydraulic pipe holes we have to be careful about leakage of oils, which will occur in overlapping of oil connections and there should be provided minimum material to withstand the hydraulic oil pressure. Figure 4 shows the base structure of weldment type. Front face will accommodate rest pads and cylindrical and diamond pins and clamp cylinders. The bottom faces rest on the Pallet. Perpendicularity tolerance will be 10 microns. After welding it should be heat treated to relive thermal stress.



Base structure (weldment)
Fig-4

2. **Rest pad**

It is made by En-353 material. Component is rest on this rest pads. Fig 5 shows the rest pad with ASC. Mainly where ever air holes are located air seat check holes are given to the rest plate to check for proper resting of the component. This rest pad is fixed to the base structure by using M6 socket head cap screws. O-rings are placed at the connection of base structure & rest pad for avoiding leakage of air. It works on pneumatics i.e. if there is any leakage of air through it, it sends signals to the machine and the machine stops.



Rest Pad with ASC

Fig-5

3. **Clamp Assembly**

Six hydraulic swing clamp cylinders are used for clamping the component in this fixture in which four swing clamps are used to clamp bottom side of component and two of them are used to clamp front side. Material used for clamp lever and cylinder mtg. block is C45

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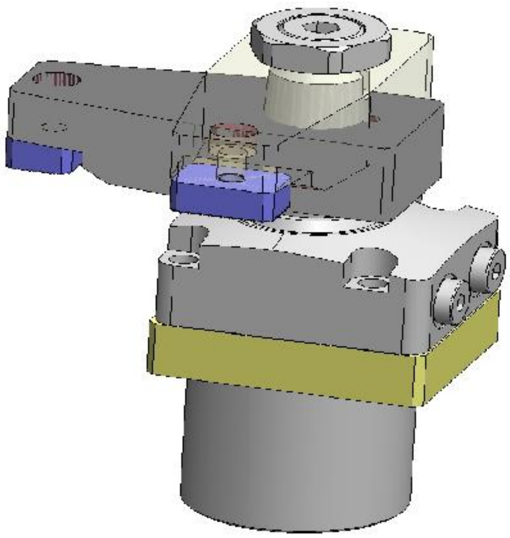
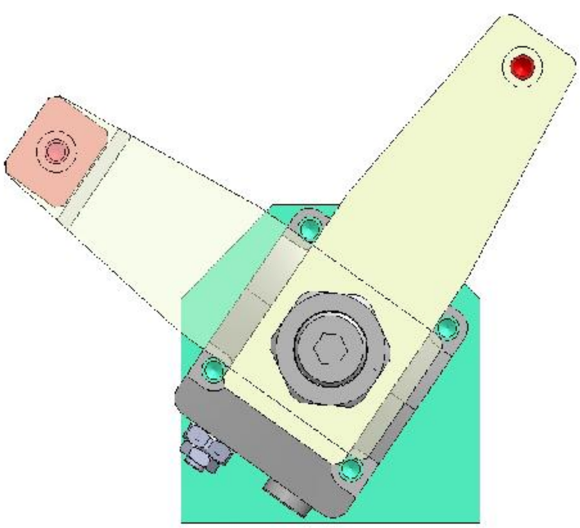
The clamp cylinders are double acting and works @ 7Mpa pressure. It gives 5 KN & 4.5KN force respectively at maximum pressure rating i.e. 7Mpa. The Hydraulic connections are given externally to weldment structure and standard hydraulic fittings. Clamp lever is fitted to this hydraulic cylinder. Material used for clamp lever is C45 which is toughened. This allows for the firm holding of the component Swing stroke is 6.5 mm. and locking stroke is 10mm.



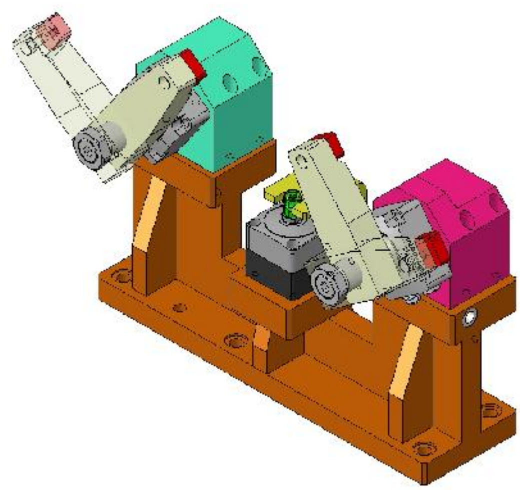
Swing clamp assembly (back side)
Fig-6



Swing clamp assembly (front side)
Fig-7

4. Front side clamp setup

Two hydraulic swing clamps are used for clamping the component in this fixture. Fig 7 shows the front clamp setup for component. The cylinders are double acting and works on 7Mpa pressure. It gives 9.0KN force at maximum pressure rating i.e. 7Mpa. To support these swing clamp cylinders a frame is designed such that both swing clamp cylinders are maintained at same height and also a work support is provided to support the component at the middle to position accurately. The Hydraulic connections are given by internal holes in the frame and standard hydraulic fittings. Clamp lever with swivel pad is fitted to this hydraulic cylinder. The clamp pad is En353 case hardening steels. This allows for the firm holding of the casting surfaces of the Transmission case. Positive stroke should be 5mm as per customer requirement.



Front side clamp setup
Fig-8

5. Rough guide

Main purpose of the rough guide is to guide component while loading and unloading of the component, fig. 9 & 10 shows rough guides used for the fixture. In this fixture two types of rough guides were used one is conventional type of rough guide and another one is bottom rough guide which is used to support the bottom side of the component while loading. Distance between the component and rough guide is 2mm. Material used for rough guide is C45

Conventional Rough guide

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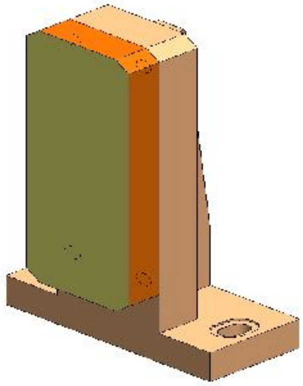
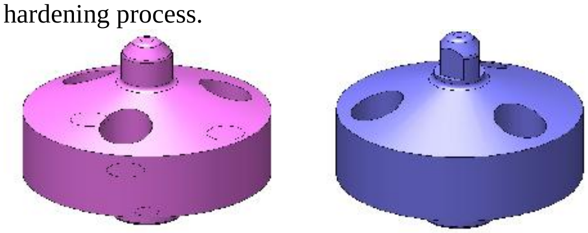
Fig-9



Bottom Rough guide
Fig-10

6. Locators

The locators must properly position the work piece and then maintain its location against primary cutting forces throughout the machining cycle. Figure 11 shows the cylindrical pin and diamond pin, taper on top of the locator should be designed for easy loading unloading .As it is a locating element it should have high hardness so the locator is made with single piece of EN353 Case harden & Tempered with 58 To 62 HRC. Threads are kept soft during hardening process.



Cylindrical pin and diamond pin
Fig-11

III STUDY OF COLLECTED DATA

- **Location and orientation**
  - Should be most accurate feature.
  - Should be geometrically related with the features, which need to be machined.
- **Resting**
  - Component shall be rested on suitable position.
  - Resting element shall be easily replaceable.
- **Clamping**
  - Component shall be clamp above the resting face.
  - Clamping face should have sufficient wall thickness.
  - To clamp casting face, serrations on clamp pad need to be provided.
  - Based on the target loading & unloading time, operator comfortable & targeted cost, Select type of clamping (manual or clamping)
- **Support**
  - Before power clamping the component, to ensure Permanent butting, a support for the Component needed

CUTTING FORCE CALCULATIONS

Cutting force calculation for face milling

Input conditions

Milling cutter diameter (Dc) = 63 mm
Cutting speed (Vc) = 800 m/min
Feed (fz) = 0.12/teeth
No. of teeth (Zn) = 5
V, f & Zn values taken from catalogues

Output conditions

Spindle speed (N) = (1000*Vc)/ (∏*D)
For D = 63mm & Vc = 800m/min
Spindle speed N = **4042 rpm**
Table feed (Vf) = fz * N * Zn mm/min
Vf = 2425 mm/min
Cutting time (T) = cutting length (Im) / (feed/t * no.of.teeth * spindle rpm)
For cutting length of 596mm
Cutting time (T) = 596/ (0.12*5*4042)
= **0.25 min**
Cutting power (Q) = (depth of cut*width of cut*table speed*specific cutting force)/ (60*10^ (6)*0.8)
So, for 60 dia cutter,
Cutting power = (2.5*63*2425*700)/ (60*10^ (6)*0.8)
= **5.57Kw**
Cutting force = (cutting power*6120)/ (cutting speed*100)
= **426 N**
Torque = (power*975)/ (100*spindle speed)
= **13.44 Nm**

Cutting force calculation for hole Ø14 Drilling

Input condition :

Drill diameter (Dc) = 14 mm
Feed (fz) = 0.18/teeth
Cutting speed (Vc) = 180 m/min
No. of teeth (Zn) = 2
Material factor (k) = 0.55 (From CMTI Hand Book)
V, f & Zn values taken from catalogues

Output condition

Spindle speed (N) = (1000*Vc)/ (∏*D)
For D= 14mm & V =180 m/min
Spindle speed N = **4100 rpm**
Table Feed (Vf) = fz * N * Zn mm/min
= 770 mm/min
Cutting time (T) = cutting length (Im) / (feed * Zn * spindle rpm)
For cutting length of 106mm
Cutting time (T) = **0.14** min
Thrust force (F (th)) = $1446*f^{0.8}*D^{0.8}+(4.31*D^2$

= **3873.91N**
Power = 1.25 * Dc^2 * K *N *(0.056+1.5 * f) / 10^5 KW
= **3.96 KW**
Torque (F (tq)) = 0.634*f^ (0.8)* D $^{1.8}$
= 12.6 N-m

Cutting force calculation for Tapping (M20)

Input condition

Tap diameter (D) = M20
Feed (fz) = 1.50mm/teeth
Cutting speed (Vc) = 35 m/min
Pitch = 1.25mm
No. of Teeth (Zn) = 1
Material factor (k) = 0.55 (from CMTI hand book)
V and f values taken from catalogues

Output condition

Spindle speed (N) = (1000*V)/(∏*D)
For D=20mm & V =35m/min
Spindle speed N = **560 rpm**
Cutting time (T) = cutting length/(feed/t* spindle rpm)
For cutting length of 46mm
Cutting time (T) = 0.26 **min**
For 75%thread engagement
Cutting power = (0.326*D*pitch^ (2)*N*k)/ 10^4 = **0.313Kw**
Torque = (power*975)/(spindle speed)
= **0.546Nm**

Cutting force calculation for Boring

Input condition

Casting hole diameter (d) = 51.5 mm
Boring bar diameter (D) = 52 mm
Cutting speed (Vc) = 160 (m/min)
Feed (fz) = 0.10/t
No. of teeth (Zn) = 2
V, f & Zn values taken from catalogues

Output condition

Spindle speed (N) = (1000*Vc)/(∏*D)
For D=52 mm & V = 160 m/min
Spindle speed N = **990 rpm**
Table Feed (f) = fz * N * Zn mm/min
= 200 mm/min
Cutting time(T) = cutting length/ (feed/t*no.of.teeth*spindle rpm)
For cutting length of 90mm
Cutting time (T) = **0.19 min**
Cutting power = ((∏*D^ (2)/4) – (∏*d^2/4) * table speed) / (1000*60*9.8)*(sp.cutting force) *10^ (6) / 0.8*1000)
Cutting power = 1.2 **Kw**
Torque = (power)/ (0.105*spindle speed)
= **11.6 Nm**

Cutting force = (torque*2000) / (tool diameter)
= **446.5 N**

Selection of clamping cylinder

In case of Crank case assy the maximum cutting force developed is 3081.91N (Drilling) which uses Ø21.1 mm drilling cutter for cutting depth/length of 119mm
Clamping Force = 3 times of Cutting force
= 3x3873.91N
= 11621.7 N
Clamping Force = **11.62 KN**
So, the clamping force should be more than 12KN while selecting the clamping cylinders.
Clamping cylinders used are model CTU06
Make: PASCAL
Clamping Force is calculated by F=P/ (1.20+0.0032*L) KN
Where P=Pressure used (7Mpa)
L=Dist. b/w centre of the clamping cylinder to the clamping point
L=58mm
F=7/ (1.20+0.0032*58)
F=5.05kN
Total Clamping cylinders planned are 4
So, the total clamping force is 4*5.05=20.20KN
As the required clamping force is more, it is recommended to go for Hydraulic Cylinders
The hydraulic elements are selected from standard catalogues available as per the requirement and applications. The straight stud fittings are used for connecting oil ports with the cylinders and G1/8" plugs are used to plug the holes.
This cylinder is used to actuate the swing clamp. This is double acting cylinder thus two lines is required for suction and discharge of oil. The piston of this cylinder is linked to the clamp lever to transmit the cylinder force to the component for holding the component securely while operation. Thus the basis for selection of this cylinder is the force required to counter the thrust force during cutting.

Outline Dimensions for hydraulic cylinder

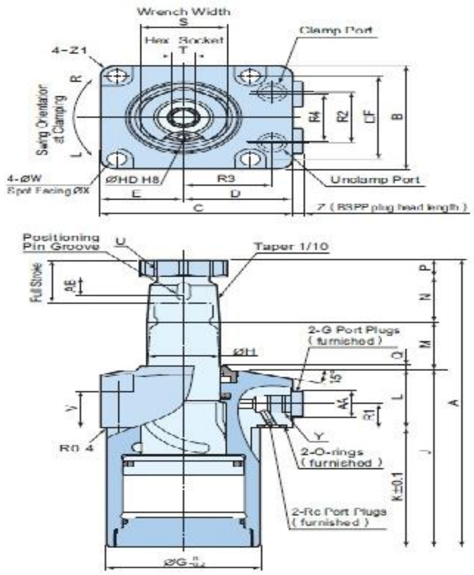


Fig-12

IV ANALYSIS OF FIXTURE BODY AND RESULTS

Analysis of the fixture body is done to check whether the fixture is withstanding the maximum cutting force during machining. Stress analysis and displacement distribution analysis is performed. Based on these results the width of the structure is decided.

Selection of Fixture Body

The customer is using horizontal machining center for the component machining. My concept is to keep the component vertically to the machine bed. For this purpose, I selected Weldment structure. This structure should withstand the cutting forces applied.

This weldment dimensions should fall under the work envelope of specific machine and it could accommodate the component and fixture elements, (i.e. Clamps, rest pads, mounting blocks etc.)

Therefore the dimensions of base plate (Fixture Base), the thickness of base plate will be decided by the analysis done using ANSYS (WORK BENCH) as below.

Base structure Displacement Analysis

A. Meshing Properties

B. Mesh Type : Solid mesh

C. Smooth Surface : On

D. Jacobian Check : 4 Points

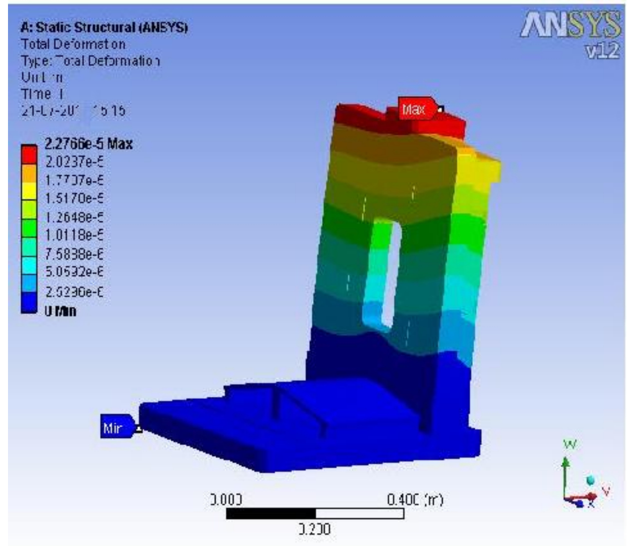
E. Element Size : 10 mm

F. Tolerance : 0.67925 mm

G. Quality : High

H. Number of elements : 40028

I. Number of nodes : 91663



Base structure displacement Plot
Fig-13

The above fig shows the displacement of the structure when the maximum cutting force is developed.

Strain displacement

S.No	Type	Min	max
1	Strain displacement	0 mm	0.023mm

Base structure stress analysis

J. Material Properties

Material : M.S (low alloy steel)

Mass : 304.184 kg

Volume : 0.038749 m^3

K. Elastic modulus : 2.1×10^5 N/mm2

L. Poisson's ratio : 0.3

M. Mass density : 7850 kg/m^3

N. Tensile strength : 1724 N/mm^2

O. Yield strength : 620 N/mm^2

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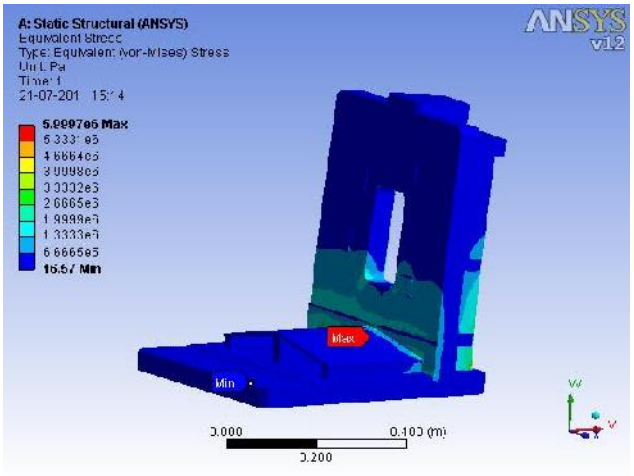

Base structure Stress analysis
Fig-14

The above fig shows the stress analysis of the structure when the maximum cutting force is developed.

Vonmisses stress

S. No	Type	Minimum	Maximum
1	Vonmisses stress	16.57 N/m^2	5.99x10^6 N/m^2

Analysis results

Stress Result

By this analysis the stress induced is 5.99MPa at maximum force of drilling (3.873KN). The maximum shear stress for mild steel is 250 MPa. So, as the shear stress developed during machining for a maximum cutting force is within the permissible limits .Thus we can conclude that the structure designed is safe

Displacement Result

By this analysis the deflection is 23 microns at maximum force of drilling (3.873KN). F.O.S for the structure is 42. Since the maximum shear stress for mild steel is 250 Mpa and the F.O.S is more than 1 it can be concluded that the structure designed is safe and it can with stand the max. Cutting forces developed during machining.

V CONCLUSION

This fixture is designed for “AVTEC TRANSMISSION CASE”. The following are the results obtained while designing and from tryout of the fixture.

- The stress developed during the maximum cutting force during machining is within the limits i.e., 5.99 Mpa.
- Displacement developed during the maximum cutting force is within the limits i.e., 23 Microns.
- As the factor of safety obtained is 42 which is more than 1, hence the design is safe.
- If the fixture is a mechanical type which takes loading time, the main advantage of this hydraulic fixture is to reduce the loading time
- Component has achieved the required accuracy.

Future scope:-

The present work is part of the process, which contains six setups for the set of operations described. It is possible to bring maximum of the operations in four setups so that the quality characteristics can be more stringently achieved.

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