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Fixture Modification of a 5- Axis CNC Machine (Makino)

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Abstract: ***Now a day's many industries use CNC machines for the production of turbo machinery components like turbine blades, impellers, rotors, propellers etc, minimum workpiece deformation due to clamping and cutting forces is essential to maintain the machining accuracy. Fixtures are work holding devices designed to hold, locate and support work pieces during manufacturing operations. Fixtures provide a means to reference and align the cutting tool to the workpiece but they do not guide the tool. The L&T – MHPS Turbine Generators Pvt Ltd company is design and manufacture turbine blade parts. Many of the parts required sophisticated fixturing in order to be machine. L&T-MHPS Company Pvt Ltd, Hazira was used fixture (MAKINO) brand and L&T Company is recently used to 4-axis CNC fixture machine. This fixture is movement of spindle and chuck rotate on x, y and z direction the motion of cutting tool A and B is spindle motion. We are design and modification of 5-axis fixture system which would eliminate the need for different fixture for each machine.***

Index Terms**:** ***Fixture, LM Guide ways, Lead Screw, Plates, Carriage, Bed***

I. INTRODUCTION

Computer Numerical Control (CNC) is one in which the motions and the functions of a machine tool are controlled by means of a prepared part program containing coded alphanumeric data. CNC can control the movements of the work piece or tool, the input cutting parameters such as speed feed and depth of cut the functions such as miscellaneous code is spindle on/off, turning coolant on/off. The program is converted into the appropriate electrical signals for input to motors that run the machine. Five axis controls provide multiple axis-machining capabilities beyond the standard three-axis CNC toolpath movements. The simultaneous contouring axes of a five-axes milling centre include the three X, Y, and Z axes; the A axis, which is a rotary tilting of the spindle or Z axis, parallel to the A axis; and the B axis, Which can be a rotary index table or an additional tilting of the spindle to the X axis.

Fig. 1 Horizontal Machining Center

A fixture is a device for holding, supporting and locating a workpiece during a manufacturing operation. Fixtures should correctly locate a workpiece in a given orientation with respect to a cutting tool or measuring instruments, or with respect to another workpiece, as for instance in assembly or welding. Such location must be invariant in the sense that the devices must clamp and secure the workpiece in that location for the specific operation.

There are many standard work holding devices such as chucks, collets, machine vises, drill chucks, etc. which are broadly utilized as a part of workshops and are usually kept in stock for general applications.

Fig. 2 CNC Machining Fixtures

Fixtures are normally designed for a definite operation to process a particular workpiece and are designed and manufactured separately. Jigs are similar to fixtures, but they not only locate and hold the workpiece but also guide the tools in boring and drilling operations. These work holding devices are collectively known as jigs and fixtures.

II. BASIC PRINCIPLE OF MAKINO A82

It is a 5-axis machine in the two additional axes is of spindle and chuck rotation besides x, y and z axis. x,y,z-axes the motion of the tool in the linear direction perpendicular to each other while 4^{th} -axis represents the angular motion of the chuck and 5^{th} - axis represents the angular motion of the spindle.

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In Makino machine, pallet moves on bed of the machine to facilitate the changing of job safely and effectively. It is utilized for the machining of HP, IP blades as well as for LP blades. LP blades are large in size as they have to face a low steam pressure. Consequently, they require large surface area to produce energy. Makino is utilized for the profile machining.

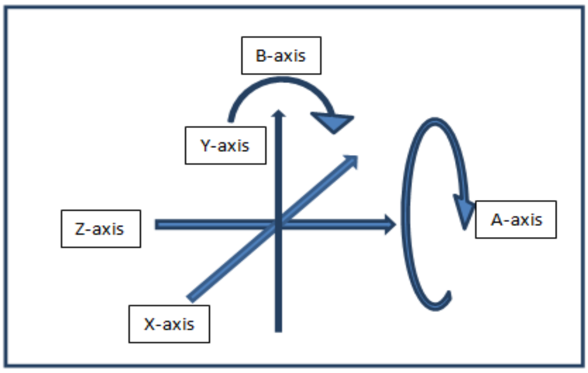
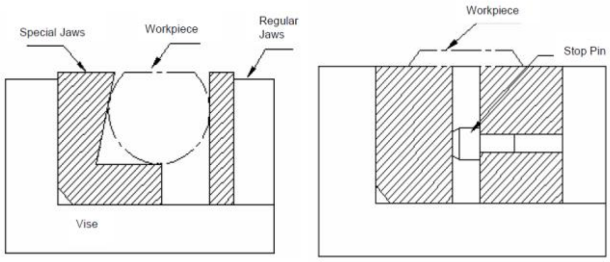


Fig. 3 HMC Machining Axes

III. TYPES OF FIXTURES

A. Vise Fixtures

It is easy to clamp workpiece with regular shape and parallel sides in a vise. However, work pieces with round or irregular shapes are very difficult to clamp properly. Henceforth, special jaws are made to hold work pieces with irregular shape properly and at the same time, it also avoids damage to the important surfaces.



(a) **(b)**

Fig. 4 Vise Fixtures

Fig4. (a) Shows simple pair of jaws for holding round workpiece. Fig4. (b) Shows pair of jaws for holding a thin sheet of non magnetic material.

B. Milling Fixtures

This holds the part in correct relation to the milling cutter. Fixture is joined to milling machine table. Milling fixture consists of the base, rest blocks or nest, clamps, locating points and gauging surfaces. The base of milling fixture consists of a base plate. A base plate has a flat level and accurate undersurface and forms main body on which various workpiece are mounted. Its surface lines up with the surface of the mill table and forms the reference plane with respect to the mill feed movement. It might be built of steel plate or cast iron, depending upon the size and complexity of the part. The slots are provided in the base for clamping the fixture to the mill table. The base plate also has keyways along with length of the base for two keys.

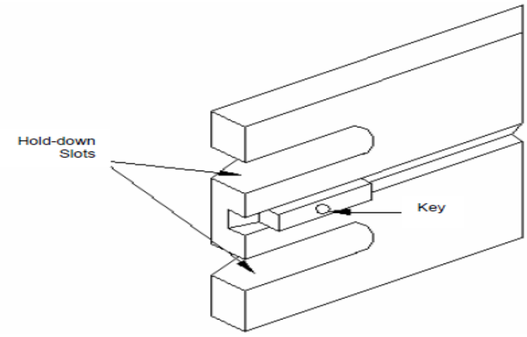


Fig. 5 Milling Fixtures

These keys are utilized to adjust the fixture on the milling machine table. The keys are pressed into the keyway at both ends of fixture and held there by socket head caps screw. This course of action has appeared in Fig 5. It is important to adjust the table by using feed movements until the correct position is attained. This can be done by trial and error cuts in the workpiece.

C. Facing Fixtures

Milling machines are widely utilized for facing seating and mating flat surfaces. Milling is frequently the first operation on the workpiece. Fig.6 shows simple face milling fixture.

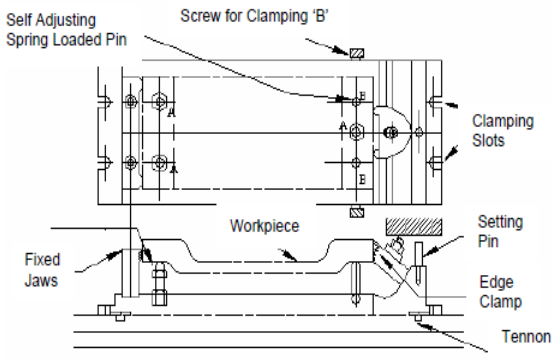


Fig. 6 Face milling Fixtures

D. Face Plate Fixtures

It can be utilized conveniently for machining of simple and small components. Addition of locators and clamps on face plate help in quick location and clamping of workpiece as shown in Fig 7. Face plate fixture is useful for facing number of work pieces simultaneously on the lathe.

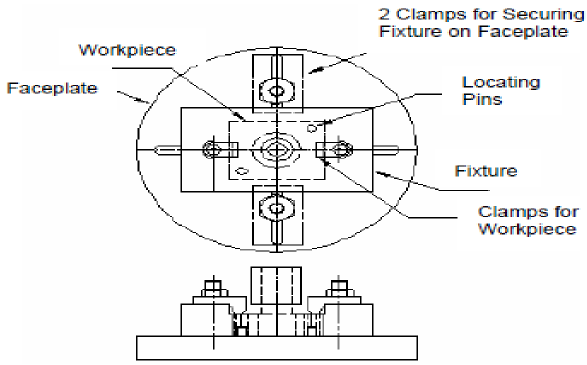


Fig. 7 Face plate Fixtures

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IV. LITERATURE REVIEW

The proposed fixturing system has been displayed to Middleton Aerospace Corporation and they are exceptionally satisfied. They have plans to execute our designs into their shop as soon as possible. These designs will consider for faster load and unload times and cut down on the number of man hours required on each operation. These changes fulfill a significant demand from Middleton Aerospace's customers to produce a large volume of parts while also maintaining quality and lowering prices.

The effectiveness and reliability of the fixture design has upgraded by the system and the result of the fixture design has made more reasonable. To reduce cycle time required for loading and unloading of part, this approach is useful. If modern CAE, CAD are utilized in designing the systems then significant improvement can be assured. To satisfy the multifunctional and high performance fixturing equipments optimum design approach can be used to provide comprehensive analyses and determine an overall optimal design. Fixture layout and dynamic clamping forces optimization method based on optimal fixture layout could minimum the deformation and uniform the distortion most effectively .The proposed fixture will satisfied researcher production target and enhanced the efficiency, Hydraulic fixture decreases operation time and improve productivity, high quality of operation, reduce accidents.

The automated in mechanism of B-Test fixture can be utilized as a part of testing to achieve better process cycle time. It is concluded that with automation in process which increases the productivity, reduce fatigue of operator and to achieve economic benefit. As the trials of the changed B-test fixture on production line were highly encouraging with respect to testing time reduction and the satisfaction by the operator as well as management as less occasions of bottlenecks. The time reduced from 7 sec to average 5 sec in initial trials, however with little refinements and enhancing test station layout it will balance to 5 sec.

V.STEPS OF DESIGN FIXTURES

A.Define Requirements

- Is the new tooling required for first-time production or to improve existing production?
- If improving an existing job, is the goal greater accuracy, faster cycle times, or both?
- Is the tooling intended for one part or an entire family of parts?

B.Analyze Information

Collect all relevant data and assemble it for evaluation. The main sources of information are the part print, process sheets, and machine specifications. Keep good notes on all ideas, thoughts, observations, and any other data about the part or fixture for later reference.

4 things that need to be taken into consideration:

- **Workpiece specifications** – Size and shape of the part, accuracy required, properties of the part material, locating and clamping surfaces, and the size of the run.
- **Operation variables –** type of operations required to make the part, number of operations performed, and sequence of operations, inspection requirements, and time restrictions.
- **Availability of equipment** – The tooling designer should verify what equipment will be used for each operation. Typically, equipment criteria include the following factors: types and sizes of machines, inspection equipment, scheduling, cutting tools, and plant facilities.
- **Personnel Considerations** – Fixture designers should put themselves in the machine operator's shoes and consider all the operational scenarios they can.

C.Develop Several Options

This phase of the fixture-design process requires the most creativity. A typical workpiece can be located and clamped several different paths. The natural tendency is to think of one solution, then develop and refine it while blocking out other, perhaps better solutions. A designer should brainstorm for several good tooling alternatives, not just choose one path right away.

The designer usually starts with at least three choices: permanent, modular, and general-purpose work holding. Each of these choises has many clamping and locating options of its own. For preparatory drawings of the fixture, use several colored pencils. Regularly black is utilized to draw the fixture, red for the part, and blue for the machine tool.

D.Chose the best Options

In analyzing fixture costs, accentuation is on comparing one method to another, rather than finding exact costs estimates are acceptable. Sometimes these methods compare both proposed and existing fixtures, so that, where possible, actual production data can be used instead of estimates.

To evaluate the cost of any work holding alternative, first estimate the initial cost of the fixture. To make this estimate, draw an accurate sketch of the fixture. Number and list each part and component of the fixture individually. Here it is important to have an orderly method for outlining this information.

E.Implement the Design

The economies of standardized parts apply to tooling components as well as to manufactured products. Standard, readily available components include clamps, locators, supports, studs, nuts, pins, and a large group of different components. Most designers could never think of having the shop make cap screws, bolts, nuts for a fixture. Likewise, no standard tooling parts should be made in-house. The first rule of economic design is: Never assemble any component you can purchase. Economically accessible tooling components are manufactured in large quantities for much greater economy. In most cases, the cost of purchasing a part is under 20% of the cost of making it. Work is generally the best cost component in the working of any fixture. Standard tooling components are one approach to cut labor costs. Browse through catalogs and magazines to find new products and application ideas to make designs simpler and less expensive.

VI. FABRICATION OF TAILSTOCK ASSEMBLY

Designing of tailstock assembly has to be done in such a way that it accommodates T-shape of moving block containing dead center holding block and maintain the center height from the base so that there is no mismatch between the centers of tailstock and headstock.

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Tailstock assembly should be provided with enough rigidity to hold the dead center assembly without any deflection or distortion of work piece. Tailstock assembly should be light enough to move in and out easily with less effect of inertia and at the same time have enough strength to withstand forces at the time of machining.

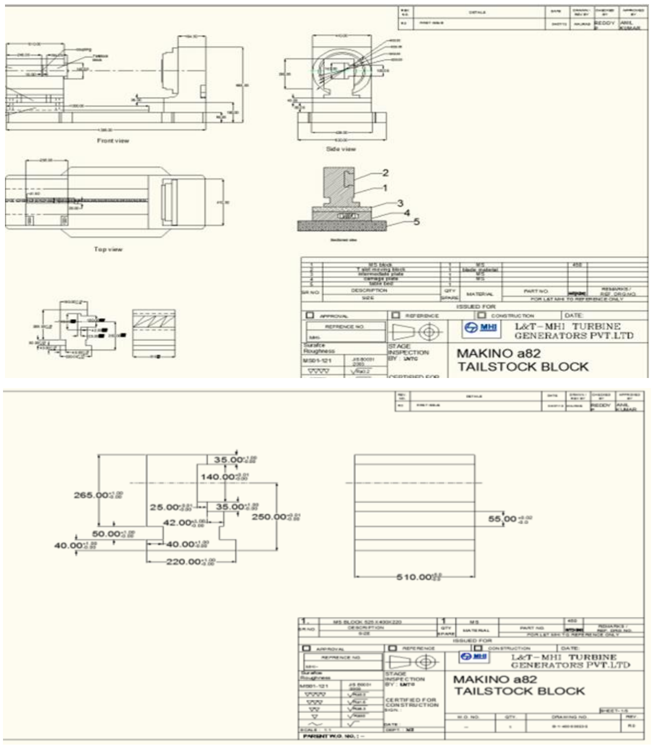
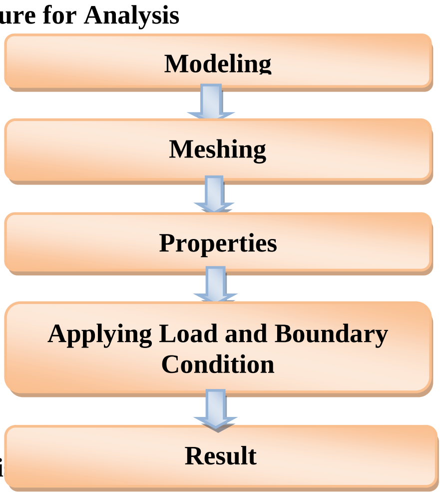


Fig. 8 Detail Drawing MAKINO a82 Tailstock Block

Tailstock assembly also accommodates many other attachments like hydraulic cylinder, attaching plates etc. fabrication of tailstock assembly starts from a M.S. block dimensioning 400 x 230 x 520. Then sizing and shaping of the block had been done on UDM (it's a horizontal boring machine) in machine shop, it's a complicated task and we have invested time and effort to accomplish it.

VII. STRUCTURAL ANALYSIS OF FIXTURE

A. Procedure for Analysis



B. Analysi

In this work modeling is carried out by using ANSYS software.

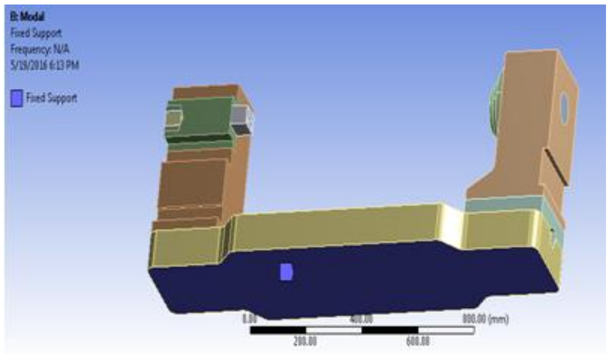


Fig. 9 Modeling in ANSYS Software

C. Assigning material properties

The material properties are given below

Table 1 Material properties

Sr. No	Properties	Range
1	Maxi. Tensile Stress	410 – 470 MPa
2	Maxi. Yield Stress	0.3
3	Poisson ratio	16.00-22.00
4	Elastic Module	210000 MPa
5	*Shear Module*	*81000 MPa*
6	Co-efficient of thermal expansion	*12*10^-6/*C*

D. Meshing

The meshing is done by using paver mesh element. In our geometry, we preferred isomesh for analysis process, and rest all meshing is paver one. When it comes to selecting the shape of elements in structures meshing, quad shape is preferred rather than tri elements because tri elements comprise of more rigidity than quad which may affect the result. So we preferred quad shape. It can carry forces and moments lying in their plane as well as transverse to their plane.

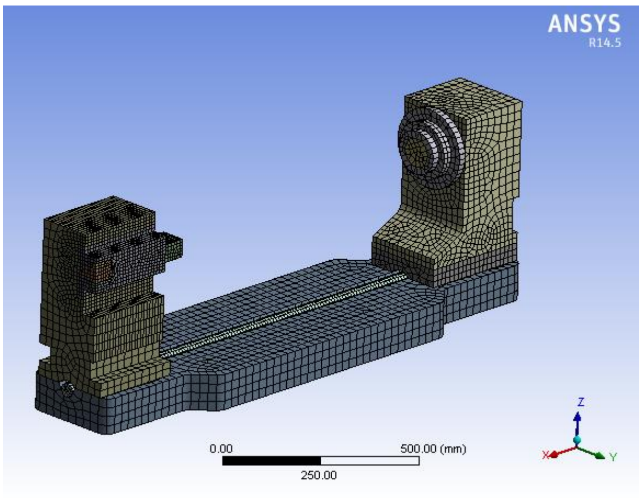


Fig. 10 Meshing

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E. Applying Boundary Conditions

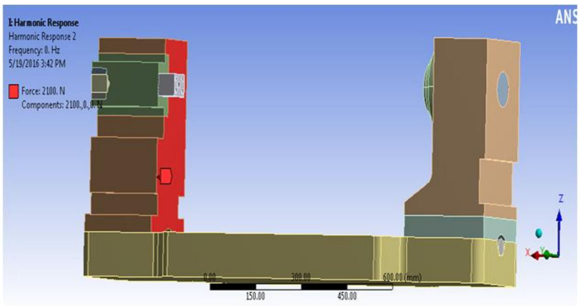


Fig.11 applying boundary conditions on Tailstock

Once the meshing, applying load and boundary conditions is over, next thing that is to be done in Finite Element Method is analysis. In analysis, various types of solution types are available such as

1. Model analysis
2. Random vibration
3. Harmonic response
4. Static structural

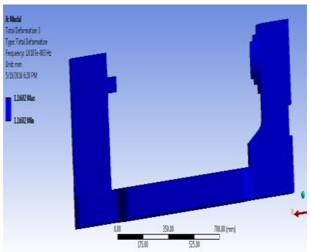
1. Model analysis

The utilized of model examination to decide the vibration qualities (common frequencies and mode shapes) of a structure or a machine segment while it is being composed. It likewise can be a beginning stage for another, more point by point, dynamic investigation, for example, a transient element examination, a symphonious reaction investigation, or a range examination. We are favored model investigation did in tailstock unit. We are connected two conditions in examination process:

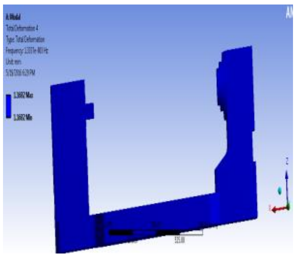
Without Fix support

With fix support

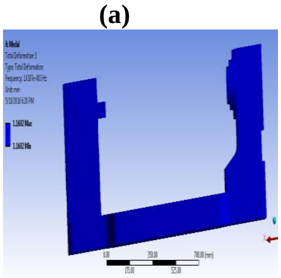
In **Without support condition**, we are obtaining the following types of deformation in analysis show in



(a)



(b)



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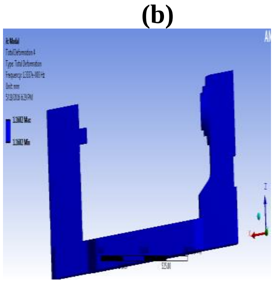

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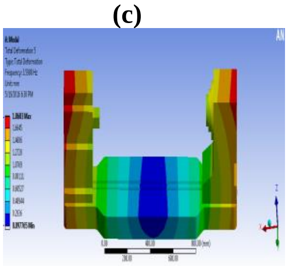
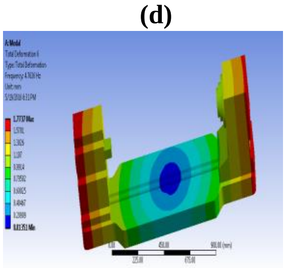


(e)



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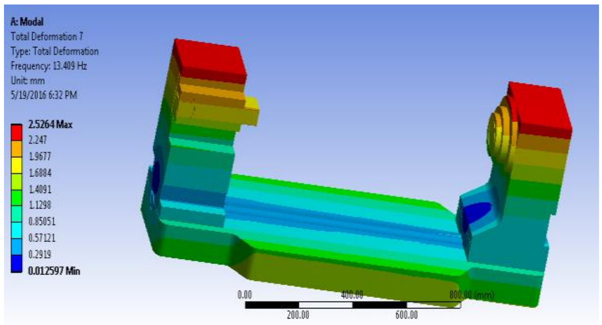

(g)

Fig. 11 Deformation

Figures demonstrate the anxiety appropriation over the apparatus a power of 2100N is connected on installation where power following up on it. After investigation it is watch that, von misses anxieties is nearly lower than standard qualities and subsequently, we can conclude that design is safe.

Table 2 without fix support Deformation

Sr. No	Total Deformation	Frequency (Hz)	Deformation in mm. (max-min)
1	(a)	0	No Deformation
2	(b)	0	No Deformation
3	(c)	1.0187e-003	No Deformation
4	(d)	1.3337e-003	No Deformation
5	***(e)***	***3.5988***	***1.8603-0.0977(Optimum Deformation)***
6	*(f)*	*4.7626*	*1.7737-0.01351*
7	*(g)*	*13.409*	*2.5264-0.012597*

With fix support condition, In This condition, we are applied fix support in bottom of the analysis model.

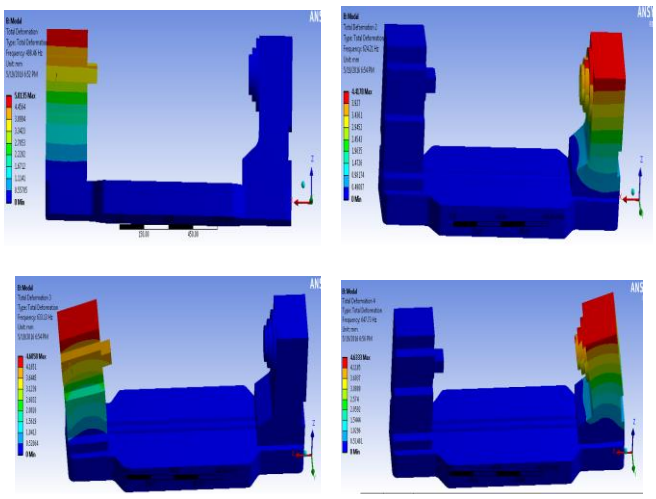

Fig. 12 Von mises stress Deformation

Figure 12 shows the variation of von mises stress. The max value of von mises stress is 5.135 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum frequency.

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Table 3 With fix support Deformation

Result	Frequency	Max-min (deformation)
1	498.46	5.135-0
2	624.21	4.4178-0
3	633.13	4.6858-0
4	647.13	4.6333-0

2. Random Vibration

The arbitrariness is a normal for the excitation or info, not the mode shapes or characteristic frequencies. Some regular illustrations incorporate a car riding on a harsh street, wave stature on the water or the heap instigated on a plane wing amid flight. Auxiliary reaction to irregular vibration is typically treated utilizing measurable or probabilistic methodologies. In numerical terms, arbitrary vibration is described as an ergodic and stationary procedure. While the term power unearthly thickness (PSD) is usually used to determine an arbitrary vibration occasion, ASD is more fitting when quickening is being measured and utilized as a part of basic investigation and testing.

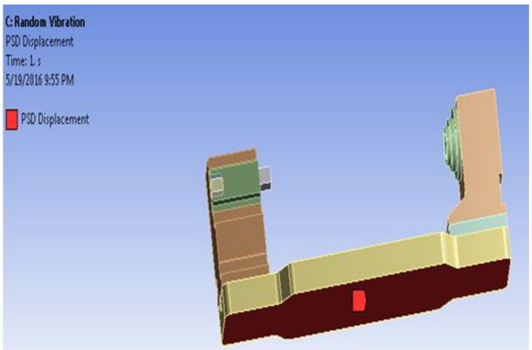

Fig. 13 Rigid Body Displacement of part (indicate by Red color)

Equivalent stress

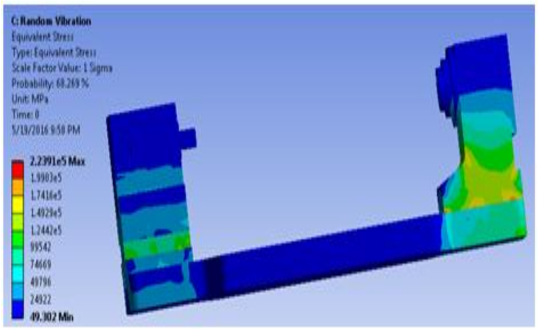

Fig. 14 Equivalent stress

Deformation in X-axis

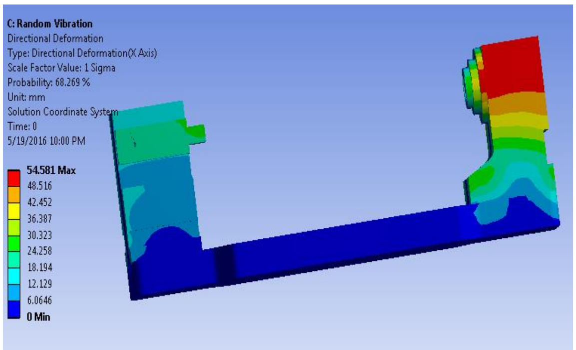

Fig. 15 Equivalent stress on X-axis

Deformation in Y-axis

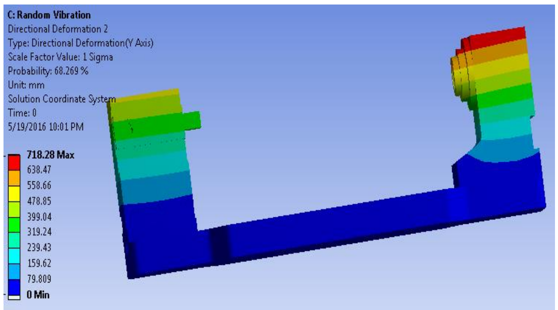

Fig. 16 Equivalent stress on Y-axis

Deformation in Z-axis

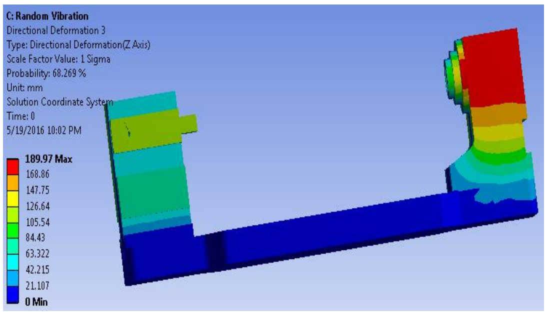

Fig. 17 Equivalent stress on Z-axis

3. Harmonic response

A technique to determine the steady state response of a structure to sinusoidal (harmonic) loads of known frequency.

We have applied 2100N load according to x direction of tailstock show in figure and after we get result of total deformation and equivalent stress.

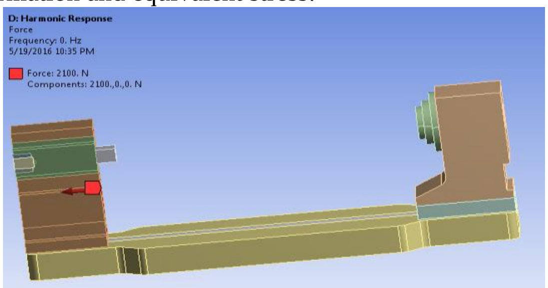

Fig. 18 Harmonic Response

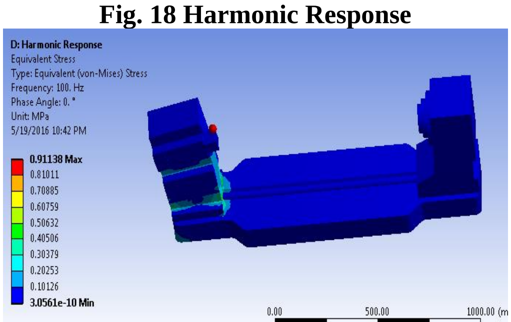

Fig. 19 Equivalent (Von-Mises) stress

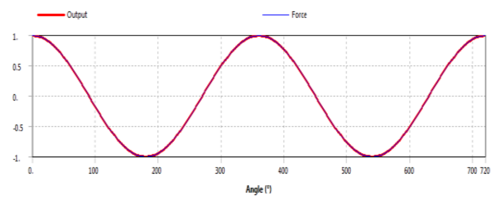

Fig. 20 Phase Response

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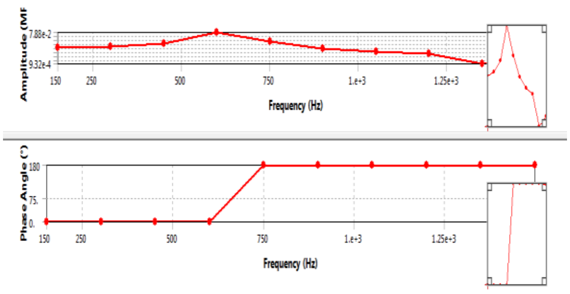


Fig. 21 Frequency response

4. Static Structural Analysis

In static analysis, the load or field conditions do not vary with respect to time and therefore, it is assumed that the load or field conditions are applied gradually, not suddenly. The system under analysis can be linear or nonlinear. Inertia and damping effects are ignored in structural analysis.

We are applied following three condition show in figure

1. Fix support in base.

2. 2100 N load applied on tailstock in x direction.

3. 219.91 rad/s rotational velocity applied on chuck.

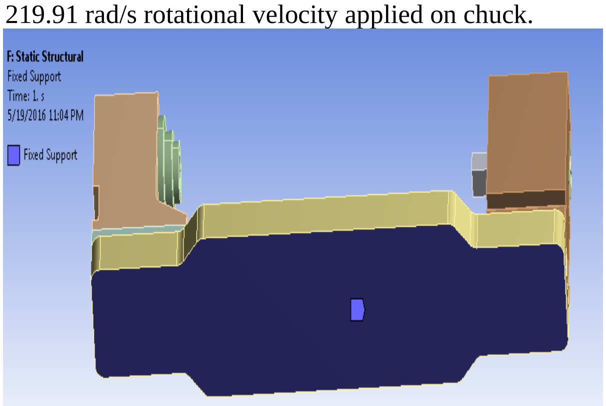
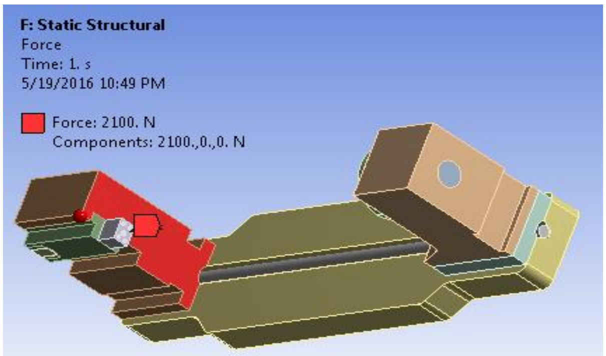


Fig. 22 Static Structural of Fixed Support



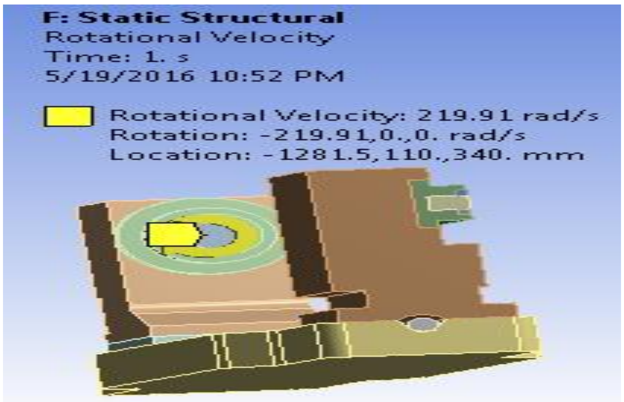


Fig. 23 Static Structural and axis rotational velocity

Equivalent stress

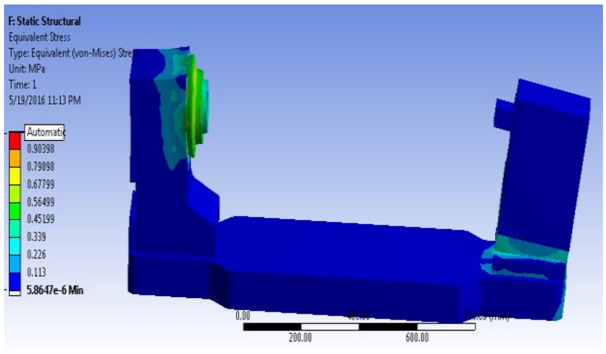


Fig.24 Static Structural Equivalent (Von-Mises) Stress of 5.8647e-6Min (Automatic)

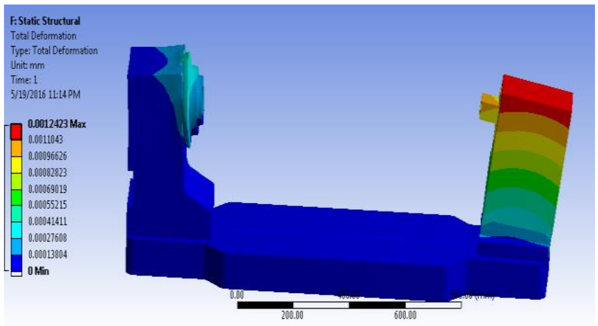


Fig.25 Static Structural Total Deformation Maxi. Stress of 0-0.0012423 Max

VIII. VALIDATION AND RESULT

BEFORE MODIFICATION		AFTER MODIFICATION	
Frequency	Deformation in mm	Frequency	Deformation in mm
0	No Deformation	0	No Deformation
0.3	No Deformation	0	No Deformation
0.9	No Deformation	1.087e-003	No Deformation
1.1258	2.589 – 1.269	1.3337e-003	No Deformation
2.4131	**3.892 – 1.162**	**3.5988**	**1.8603-0.0977 (Optimum deformation)**
3.5826	3.69-0.60139	4.7626	1.7737-0.01351
6.5912	5.781-1.0689	13.409	2.5264-0.012597

When applied different frequency (1.0187-003, 1.337-003) on part of the object then get no any result. After increase the value of frequency (3.598) then get the deformation i.e. called optimum deformation.

IX. CONCLUSION

Analysis carried on the assembly of the fixture gives good result where the stress and deformation formed on the materials of the fixture assembly are under the limit which is less than the yield strength of material and hence there is no chance of failure. The ANSYS result was also validated theoretically and gives good accuracy for result.

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The design of the fixture is simple, these design will allow for faster load and unload and cut down on the number of man hours required on each operation. which in turn decreases the handling and machining time the fixture in such a way that any operation are suppose to be done at certain angle can be easily performed on this fixture as we can perform the machining number of parts considering static force over the component which is in the contact with the fixture is analyzed, it show the total deformation and the stress acting on the fixture during the machining process done on the fixture. Hence the design is safe as result to improve the performance of the makino machine A82. The following improvement:

To reduce vibration in blade mounted on the machine
To achieve required pressure to clamping the work piece (blade).To provides better clamping the work piece (blade).
The above improvement in tailstock achieved by using hydraulic fixture mounted in the tailstock.

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