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Design, Development and Manufacturing of Dedicated Fixture for the NRV Body Component for Drilling & Tapping Operations on 4th axis Rotary Table VMC

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Abstract - *The objective of this paper is to design, developed a dedicated fixture for the NRV body component for the machining of drilling & tapping operations within minimum only one setup on the 4th axis rotary table VMC. At first component features studied, suitable conceptual & detailed layout is drawn is Solidworks. Limits, Fits & Tolerances given for the fixturing component in between mating component wherever necessary. Each fixturing component is designed then ANSYS software used for comparison of deflections & stresses.*

Key Words: **VMC, Solidworks, Ansys, NRV body component**

1. INTRODUCTION

The fixture is a device which is used to locate, hold & clamp the given component in a respective position also it is used to guide the tool with the help of jig plate & bushes. The value of the fixture design & manufacturing is nearly 10-20% of the manufacturing process. There are various types of fixtures according to their applications like machining fixture, Assembly fixture, Inspection fixture etc. The machining fixture is classified mainly two types dedicated fixture & modular fixture. If mass production is there the dedicated fixture is used. & its setup cannot change. when the production is of batch type the modular fixture used. because it can accommodate the similar product in the batch as it is reconfigurable fixture. The use automation of fixture design is called as computer aided fixture design that results in the lower time required for the fixture design because the traditional method of fixture design of trial & error method is completely avoided. Many software's are used for the fixture design. The ultimate aim of any fixture design is to manufacture the given component with the accuracy such that the loading & unloading time of the component would be lower as possible as possible so that the operator fatigue is reduces that surely helps to increases the productivity of given component. To achieve the interchangeability of components fixture has significant role & directly affect the accuracy of component. The fixture design may be multi modal solutions by considering the fixturing generic requirements the fixturing layout which fulfils all the aspects that fixturing layout is selected as best fixturing layout for any given component. Modular fixture contains set up of standard elements which can assembled to form the fixture for various sizes of suitable range component.

1.1 Fixture Design

The fixture consist of many elements like locating system, clamping system & supporting system. Each of them having different types of elements according to its suitability to the component they are selected. The most significant part in the fixture is the locators. The locator should be place such that it is easy to every time mount the given component & clamping system should be such that it exerts the force against the locator. Types of locators are Round & diamond pin, Floating locating pins, Bullet nose dowels, Bullet nose pins, Cone locator pins etc & diamond pin locator is used two compensate the gap between two locating surface. Type of clamping are strap clamp, hinged clamp, quick action clamps, power operated clamps etc. The clamping characteristic should be such that position of clamping force on the supported part of workpiece. The strength of clamping force should be enough to fix the workpiece. If more number of clamps are needed for respective fixture then power operated clamping is suitable to prevent the more time for loading & unloading of component & operator fatigue.

Mainly their are four steps for the fixture design setup planning, Fixture planning , Unit design , Verification. Before the actual fixture design process is started the input for all the step is component cad model & machining operation information. Setup planning shows that the component is oriented in a respective direction by taken into consideration of machining features on the component & when other group of machining feature is to be carry out then the position & orientation of the component is changed.

In Fixture planning desirable requirement & characteristic of respective fixture & fixturing layout are find out.

In unit design the various types of element is required for the fixture designing & has to be assemble the locating system, clamping system & supporting system. The conceptual unit design & detail unit design needs to be carry out.

Last stage is the fixture design verification against the desirable outputs of fixture i.e. check the desirable requirement of the fixture is fully satisfied or not.

1.2 Objective

The objective of this paper are –

a. To design dedicated fixture for the drilling ø11 mm for 4 Nos. Of holes & Tapping M6×1 deep 10mm 5 Nos. Of tapping.
b. To do fixture planning for combining mentioned operations in a single setup.
c. To manufacture the dedicated fixture.

1.3 Methodology

a. Study of NRV body component.
b. Study of location system.
c. Study of clamping system.
d. Conceptual Idea generation of different possible fixturing layouts.
e. Selection of best fixturing layout considering its fixturing requirements.
f. Modelling in Solidworks software.
g. Design of individual fixturing elements.
h. Limits, Fits & Tolerances used wherever necessary between the mating components.
i. Assembly of fixturing elements.
j. Manufacturing of fixture.
k. Static analysis is carried out by Finite element method using ANSYS software for comparing Analytical calculations with numerical values of FEA.

2. LITERATURE REVIEW

Latin Boyle et al, Globalization leads enhancement in the product variety. To fulfil the demand of customer the manufacturer should rapidly design & manufacture particular component in very less time this can be achieve by the computer aided fixture design. The steps required in CAFD is given & there approaches are described. To make manufacturing system sufficient flexible research is carry out. Focus should be on the fixture physical structure & its supports. [1]

Necmettin Kaya, Due to machining the deformation of workpieces may cause dimensional error in the machining. To prevent the deformation alter the positions of locators, clamping & optimize it by using genetic algorithm. The combination of genetic algorithm & FEA method is effective for solving optimized problems. The conclusion of this approach shows that fixture layout optimization problem are multimodal problem. The optimize layout might be look different but its function is to provide similar performance. [2]

Patel & Acharya, Hydraulic fixture is designed for the yoke industrial component. The large number of clamping used initially with manually. So the worker required more time to clamp all the clamps. By using hydraulic fixture at a same time all clamps operated. So the loading & unloading time required for the component is reduced. So productivity of component increases & fatigue of worker reduces. [3]

Hashemi & Shsharou, Cased based reasoning one of the significant methodology of computer aided fixture is discussed. Past data base is taken as reference for the current fixture design. Genetic algorithm is generally used for optimization of fixture layout. Finite element approach is used for the deformation analysis. More focus in future should be on more stiffness of supporting unit design. [4]

R. Forstmanna et al., As product variety varies the customer demands needs to be satisfied so there is a need of quick manufacturing this is possible by making automated of fixture design process is called computer aided fixture design. Loading the 3D file of component into the algorithm which generates output as a fixture design if the fixture has to be deisgn without investing more time & money. In rapid fixture design the component is loaded in solidworks, visual basic tools are executed by creating standard support & locator. And assembly done. [5]

R. Hunte et al, The automation of fixture design is called as computer aided fixture design. The integration of component study, machining features details, conceptual & detailed design, fixture requirement design & interpretation rules. The knowledge templates are developed to reduce the time spend to generation of new fixture design effectively.[6]

2.1 findings from literature review

a. The optimized positioning of clamps & locators can minimize the elastic deformation of workpiece which reduces the machining error.

b. As the fixture is hydraulic type it reduces the cycle time for clamping & declamping, Reduction in operator fatigue & increase in productivity & also reduction of wear and tear of components.

c. As the CAFD approach is used so that time required for the design the fixture is lower, the input data are the CAD model of workpiece & machining requirements. The output data are the CAD models of needed workpieces.

d. Fixture designing by means of referencing past design process to generate conceptual fixture design quickly.

e. Designing the fixture Catia / Solidworks software used.

f. Formulating a methodology that will automate the fixture design process.

3. STUDY OF COMPONENT

Fig.1-Front view and Top view of NRV body component

Component details:
a. Material – Grey cast iron
b. Weight of component- 3.13Kg
c. Operations to be performed- Drilling of drilling ø11 mm for 4 Nos. Of holes & Tapping M6×1 deep 10mm 5 Nos. Of tapping.

Figure -2: NRV body component

3. REQUIRED DATA FOR FIXTURE DESIGN

Table -1: Data required & outcomes for fixture design

SR.NO.	RQUIRED DATA	OUTCOMES
1.	Component details: 2D drawing, pre-machined & machined operations to be performed, Orientation of component, Material, Hardness, Co-efficient of friction of material, Strength Etc.	Locating position Camping position & supporting positions.
2.	Machining operation & Mechanical properties: Spindle speed Feed Depth of cut Width of cut	To calculate cutting forces & Torque required.
3.	Machine details: Maximum movement of spindle , Machining bed details, ATC etc.	To check workpiece-Fixture & tool interference.
4.	Cost Investment:	To decide type of clamping manual or power clamping.
5.	Properties of material : Yield strength, Hardness, Density, Poisons ratio , Modulus of elasticity, Hardness	To do FEM analysis.

4. CONCEPTUAL IDEA GENERATION OF FIXTURING LAYOUTS:

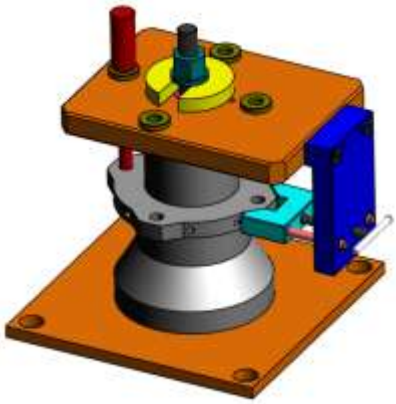

Figure -3 : 1st Fixturing layout

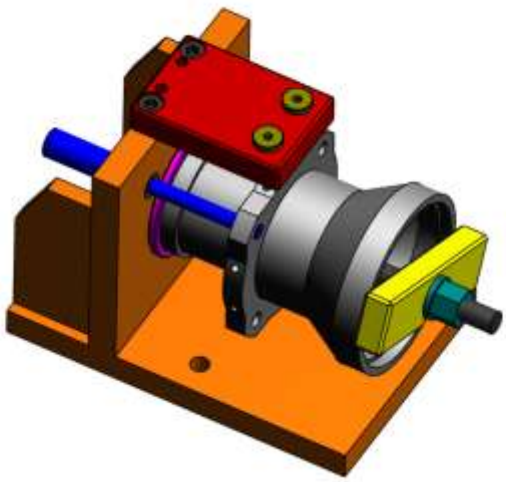

Figure- 4: 2nd Fixturing layout

By carefully observing this two layouts. In first layout only vertical holes drilling of ø11 mm for 4 Nos. Of holes is possible but cannot perform drilling ø5mm & tapping 6mm 5Nos.of holes in the horizontal direction. In the second fixturing layout it is vice-versa the required machining operations cannot achieve on individual setup. Even though by using this two layout the required machining operation can performed. But its drawback is two fixture setup required. Loading & unloading time will be more. As the orientation & positions of component changes so it can affect on the accuracy & productivity. To overcome this the suitable & more efficient fixturing layout is shown below.

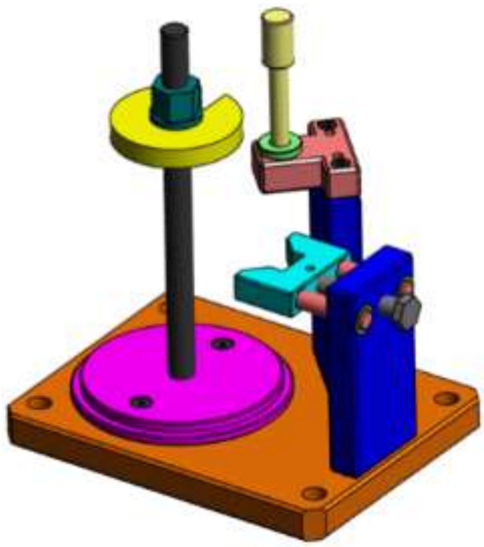

Figure- 5 : 3rd Fixturing layout

In this layout the machining of drilling ø11 mm for 4 Nos. Of holes is possible & & Tapping of M6×1 deep 10mm 5 Number Of tapping also possible by using 4th axis VMC rotary table machine so that the fixture can rotate 90˚ to back side & again rotating 180˚ to its front side . Such that within single setup all the machining operations can carry out.

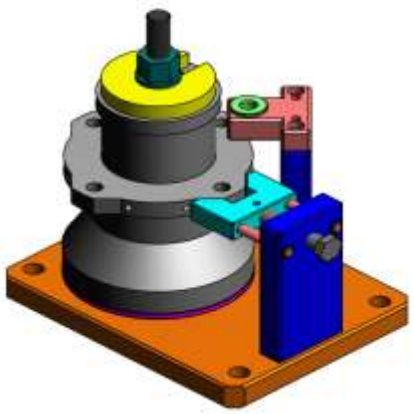

Figure-6 : 3rd Fixture for 4th axis VMC

5. DETAILS OF BEST FIXTURING LAYOUT:

The best fixturing layout is the 3rd layout for the 4th axis VMC. Table shown individual fixturing elements and its material selection & its quantities are listed.

Table – 2: Fixturing element bill of material

SR.NO.	FIXTURING ELEMENTS	MATERIAL	QTY.
1	Base plate	MS	1
2	Vertical plate for orientation pin	MS	1
3	T block	MS	1
4	V block	EN31	1
5	Locator	EN31	1
6	Bush for orientation pin	EN31	1
7	Orientation pin	EN31	1
8	Liner	EN31	2
9	C washer	EN8	1
10	Hexagonal Nut	EN31	1
11	Guide pin for V block	EN31	2
12	Hexagonal bolt	EN8	1
13	Stud	EN31	1
14	Hexagonal socket head cap screw M6	EN8	2
15	Hexagonal socket head cap screw M8	EN8	4
16	Slotted countersunk head cap screw M6	EN8	2
17	Dowel pin ø 6mm	EN8	2
18	Dowel pin ø 8mm	EN8	4
19	Vertical plate for V block	MS	1

5.1 Analytical force calculation for drilling operation for drilling of diameter of 11 mm:

Following input parameters are used to calculate the cutting force calculations in 4th axis VMC.

Table- 3: Specification of drilling operation for ø11 mm

SR. NO.	PARAMETERS	VALUES
1	Drilling diameter	11mm
2	Cutting speed	23m/min
3	Feed per revolutions	0.2 mm/rev

Revolution/min (RPM):

$V = \pi \times D \times n / 1000$
$n = 23 \times 1000 / \pi \times 11$
$n = 666$ rpm

Power at the spindle (Kw):

$N = 1.25 \times D^2 \times K \times n \times (0.056 + 1.5 \times s) / 10^5$
$N = 1.25 \times 11^2 \times 1.5 \times 666 \times (0.056 + 1.5 \times 0.2) / 10^5$
$N = 0.537$ Kw

Power at motor (Kw):

$Ne = N / E$
$Ne = 0.537 / 0.8$
$Ne = 0.672$ Kw

Torque at spindle (N-m) :

$T = 975 \times N / n$
$T = (975 \times 0.537) / 666$
$T = 7.71$ N-m

Cutting force (N) :

$F = 1.16 \times k \times D \times (100 \times S)^{0.85}$
$F = 1.16 \times 1.5 \times 11 \times (100 \times 0.2)^{0.85}$
$F = 2395.99$ N

5.2 Analytical force calculation for drilling operation For drilling of diameter of 5mm:

Table - 4: Specification of drilling operation for ø5 mm

SR. NO.	PARAMETERS	VALUES
1	Drilling diameter	5 mm
2	Cutting speed	23m/min
3	Feed per revolutions	0.13 mm/rev

Revolution/min (RPM):

$V = \pi \times D \times n / 1000$
$n = 23 \times 1000 / \pi \times 5$
$n = 1465$ rpm

Power at the spindle(N) :

$N = 1.25 \times D^2 \times K \times n \times (0.056 + 1.5 \times s) / 10^5$
$N = 1.25 \times 5^2 \times 1.5 \times 666 \times (0.056 + 1.5 \times 0.13) / 10^5$
$N = 0.17$kw

Power at motor (Ne) :

$Ne = N / E$
$Ne = 0.1723 / 0.8$
$Ne = 0.2154$ kw

Torque at spindle (T) :

$T = 975 \times N / n$
$T = (975 \times 0.17) / 666$
$T = 1.124$ N-m

Cutting force (N) :

$F = 1.16 \times k \times D \times (100 \times S)^{0.85}$
$F = 1.16 \times 1.5 \times 5 \times (100 \times 0.13)^{0.85}$
$F = 755.07$ N

5.3 Analytical torque calculation for tapping operation:

Table -5: Specification of tapping operation for ø6 mm

SR. NO.	PARAMETERS	VALUES
1	Tapping diameter	6 mm
2	Cutting speed	11 m/min
3	Pitch	1 m

Revolution/min (RPM):

$V = \pi \times D \times n / 1000$
$n = 11 \times 1000 / \pi \times 6$
$n = 666$ rpm

Power at the spindle (75% of thread engagement) :

$N = 0.326 \times p \times n \times k / 10^4$
$N = 0.326 \times 1 \times 584 \times 1.5 / 10^4$
$N = 0.0285$ Kw

Power at motor (Nel):

$Nel = N / E$
$Nel = 0.0285 / 0.8$
$Nel = 0.0356$ Kw

Torque (N-mm) :

$T = 975 \times N / n$
$T = (975 \times 0.0285) / 584$
$T = 0.465$ N-m

5.4 Analytical stress and deformation calculation:

Hexagonal Bolt:

Table - 6: Input parameters for stress calculation of Hexagonal bolt

SR. NO.	PARAMETERS	VALUES
1	Moment	33223.08 N-mm
2	I	$1017.873mm^4$
3	Y	6mm

$M / I = \sigma b / Y$
$\sigma b = (33223.08 \times 6) / (\pi \times D^4 / 64)$
$\sigma b = 195.83$ Mpa

$\delta = (P \times L^3)/(3 \times E \times I) = 0.105$ mm

Guide pin for V block:

Table – 7: Input parameters for stress calculation of guide pin for V block

SR. NO.	PARAMETERS	VALUES
1	Moment	33223.08 N-mm
2	I	1017.87 mm^4
3	Y	6mm

M / I = σb / Y
$\sigma b = (33223.08 \times 6) / (\pi \times D^4 / 64)$
σb = 195.83 Mpa

$\delta = (P \times L^3)/(3 \times E \times I) = 0.105$ mm

Orientation pin:

Table - 8 : Input parameters for stress calculation of orientation pin

SR. NO.	PARAMETERS	VALUES
1	Moment	21141.96 N-mm
2	I	718.68 mm^4
3	Y	5.5 mm

M / I = σb / Y
$\sigma b = (18876.75 \times 6) / (\pi \times D^4 / 64)$
σb = 144.46 Mpa

$\delta = (P \times L^3)/(3 \times E \times I) = 0.0200$ mm

Stud:

Table - 9 : Input parameters for stress calculation of stud

SR. NO.	PARAMETERS	VALUES
1	Moment	89098.26 N-mm
2	I	3216.99 mm^4
3	Y	8mm

M / I = σb / Y
$\sigma b = (89098.26 \times 8) / (\pi \times D^4 / 64)$
σb = 221.56 Mpa

$\delta = (P \times L^3)/(48 \times E \times I) = 0.260$ mm

5.5 Limits, Fits & Tolerances:

For the tolerance provided between maing part the hole basis system is selected. And H7 is selected as basic tolerance grade for hole.

Table- 10: Limits, Fits & Tolerances

Mating Parts	Shaft tolerance grade	Tolerance on Hole	Tolerance on shaft	Type of fit
Base plate & locator	Ø30p6	+21 0	+35 +22	Int. Fit
Vertical plate for V block & linear	Ø18m6	+18 0	+18 +7	Transit. Fit
Linear & guide pin for V block	Ø 12g6	+18 0	-6 -17	Clr. Fit
T block & Bush	Ø18p6	+18 0	+29 +18	Int. fit
T block & vertical plate by dowel pin	Ø6m6	+12 0	+12 +4	Transit. fit
Vertical plates & Base plate by Dowel pin	Ø8m5	+15 0	+12 +6	Transit. fit

Figure -7 : Fixture without component

Figure -8: Fixture with NRV Body component

5.6 FE Analysis:

Here ANSYS 18 static workbench software is used for FEA of CAFD's. Boundary conditions & material properties used for this FEA is shown in table 11.

Table –11 : Material properties of fixturing element

PARTS	MATERIAL PROPERTY	YOUNG'S MODULUS (GPA)	POISSON'S RATIO	Density Kg/m^3
Hexagonal bolt	EN31	200	0.28	7800
Guide pin for V block	EN31	200	0.28	7800
Orientation pin	EN31	200	0.28	7800
Stud	EN31	200	0.28	7800

Hexagonal Bolt:

i) Solid modeling:This elements are designed in the solidworks software & the solidowork model is imported in ansys software in the form of .stp file for static structural analysis.

ii) Material: properties for EN31 Material are given in the table 11.

iii) Contacts & Meshing: The contact types are bonded. Later meshing is done dividing the component into number of parts.

iv) Boundary conditions for structural analysis: The force of magnitude 755.07 N is applied at the end point of the hexagonal bolt. Its other end is fixed.

V) Results of analysis: The total deformation in the hexagonal bolt is shown 0.113 mm & maximum principal stress is 338.59 Mpa.

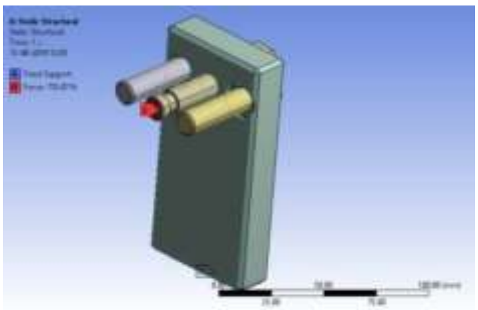

Figure -9 : Boundary condition & load for hexagonal bolt

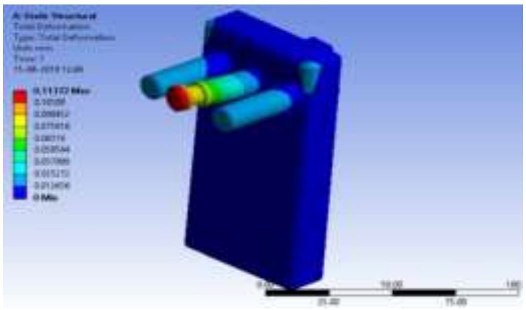

Figure -10 : Deformation plot of Hexagonal bolt

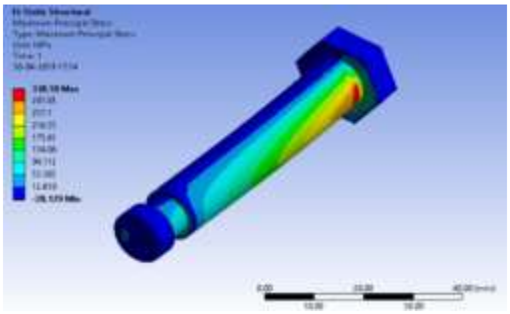

Figure -11 : Maximum principal Stress plot of Hexagonal bolt

Guide pin for V block:

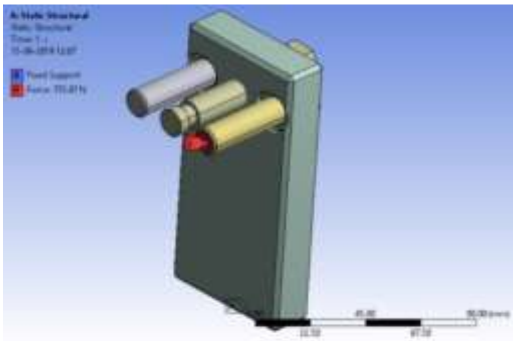

Figure – 12 : Boundary condition & load for guide pin for V block

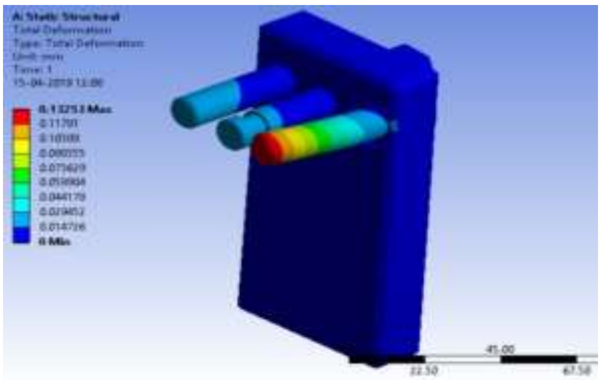

Figure -13 : Deformation plot of guide pin for V block

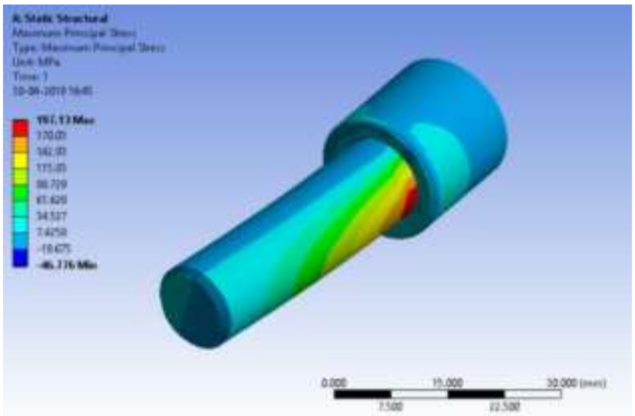

Figure -14 : Maximum principal Stress plot of guide pin for V block

Orientation pin:

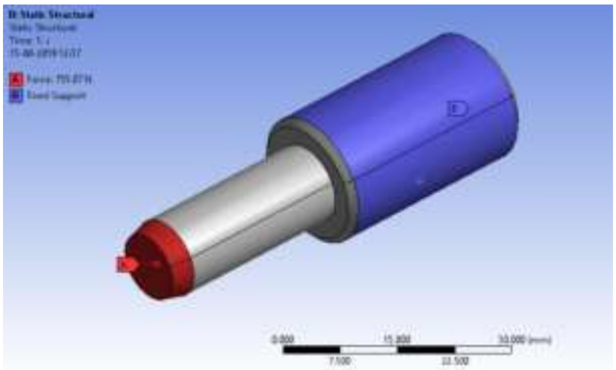

Figure – 15 : Boundary condition & load for orientation pin

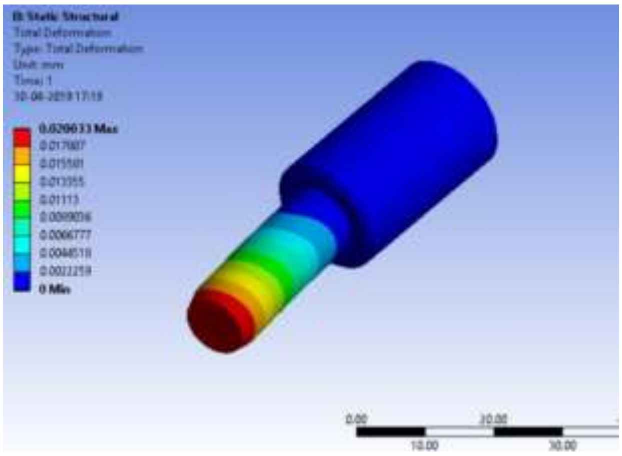

Figure -16 : Deformation plot of orientation pin

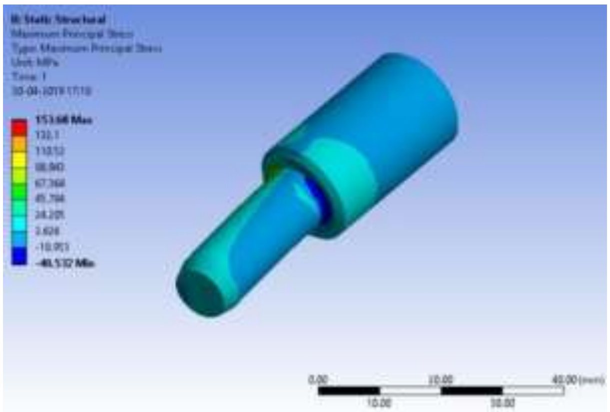

Figure -17 : Maximum principal Stress plot of orientation pin

Orientation pin:

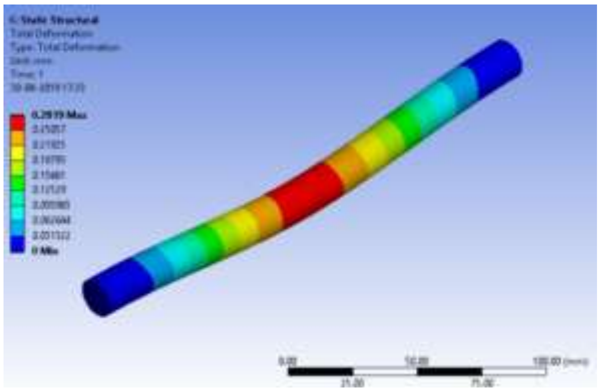

Figure -18 : Deformation plot of stud

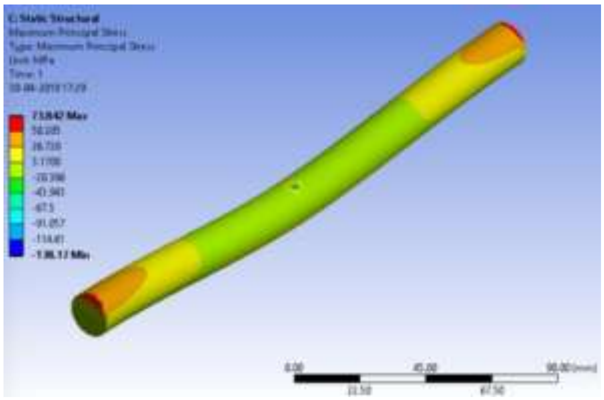

Figure -19: Maximum principal stress plot of Hexagonal bolt

5.6 Results & Discussion:

Table – 12: Comparison of Analytical deformation with FE deformation results with maximum principal stress

Critical Elements	Analytical Results (mm)	FEA result (mm)	Error (%)	Max. principal Stress (mpa)
Hexagonal Bolt	$\delta = 0.105$	$\delta = 0.113$	7.61	σp=338.5
Guide pin for V block	$\delta = 0.105$	$\delta = 0.132$	25.71	σp=197.1
Orientation pin	$\delta = 0.0200$	$\delta = 0.0204$	2	σp=153.6
Stud	$\delta = 0.260$	$\delta = 0.281$	8.07	σp=73.84

The maximum principal stress in the hexagonal bolt, Guide pin for V block, orientation pin & stud is less than the yield strength or ultimate tensile strength value so design is safe.

6. CONCLUSIONS:

1. The value of the stresses and deflections are within its limit. Hence design is safe.

2. The Analytical values & FE values comparatively shows good results.

3. The change in orientation & position of component can completely avoided, Reduction in the orientation & position of the component reduces error in machining operations so it increases accuracy.

4. Fixture is successfully designed & manufactured for the NRV body component within minimum setup on the 4th axis VMC to increase the productivity & accuracy.

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