DESIGN OF MACHINING FIXTURE FOR TURBINE ROTOR BLADE

C.RadhaMadhavi[1], B.Ramu[2], K.Srinivasulu[3]

[1]*Design Engg. in Sri Venkateshwara Mechanical & Electrical India L.td., Hyderabad, AP, India.*
[2]*Asst. prof in Mech Engg, Anurag College of Engineering, Aushapur, Hyderabad, AP, India*
[3]*Associate. prof in Mech Engg, Anurag College of Engineering, Aushapur, Hyderabad, AP, India*

Abstract

This Project presents the Design of Machining Fixture for Gas Turbine Rotor Blade for Machining on VMC (Vertical Machining Centre). Fixture Design consists of High product rate, low manufacturing operation cost. The fixture should be designed in such-a-way that part/product change overtime is very less. The report consists of study of input data from customers like Part drawing and Assembly drawing. The fixture design begins with part modeling, Machining and Analysis of various parts in the fixture assembly using AutoCAD and Solid works, for a analysis COSMOS Software package is used. The actual design begins with study details of project proposal summary from customer. After that machining fixture concept is done. Locating and clamping points are decided. This also includes accessibility, loading and unloading sequence of parts, required material for this fixture is selected, and Fixture is designed at SRI VENKATESWARA MECHANICAL AND ELECTRICALENGINEERING INDUSTRIES, Hyderabad using Industrial application standards. Locating accuracy and machined part quality tested and found that the fixture is as good as any dedicated fixture in production.

Keywords: *Vertical Machining Centre, AutoCAD and Solid works, COSMOS Software.*

---***---

I .INTRODUCTION

This project is intended to design and develop a machining fixture for the gas turbine rotor blade. Machining fixture requires systematic design to clamp, hold and guide the tool during machining process. Using the design data and geometry of the component fixture is designed to hold the part with less time for loading and unloading the part.

1.1. Machining Fixtures

The obvious place for Fixtures is in mass production, where large quantity of output offers ample opportunity for recovery of the necessary investment. It 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

1.2. Purpose of Machining Fixtures

The main purpose of the fixture is to locate the work quickly and accurately, 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.

By maintaining or even improving the interchangeability of the parts, a jig or fixture contributes to a considerable reduction in the cost of assembly, maintenance and the subsequent the potential of standard machines and the quality of the parts are produced. One important goal, to design a fixture in such a way as to make it foolproof, and there by contribute to added safety for the operator as well as for the machine tools and other parts being used.

1.3. CLASSIFICATION OF FIXTURES

Fixtures are classified according to following factors.

Application Based	**Purpose Based**
1. Work holding fixtures	1.Unioverasal fixture
2. Tool holding fixtures	2. Re settable fixtures
3. Fit- up fixtures	3.UCF
4. Gauging fixtures	4. UAF
5. Holding fixtures	5.Specialized fixtures

Based On Degree of Mechanization and Automation

1. Hand operated
2. Power operated
3. Semi automatic
4. Automatic

Based On Operation

1. Milling fixtures
2. Turning fixtures
3. Grinding fixtures
4. Broaching fixtures
5. Welding fixtures

6. Assembly fixtures

1.4. Elements of Fixtures

Five considerations are important, of which the first two are common to both jigs and fixtures, the third applies to jigs only, and the last two only to fixtures.
a) Location b) Clamping c) Guidance
d) Setting of cutters e) Securing to the machine table

1.5 Advantages of Jigs and Jixtures

Productivity: Jigs & Fixtures eliminate individual marking, positioning and frequent checking. This reduces operation time and increase productivity.

Interchangeability: Jigs & Fixtures facilitate uniform quality in manufacture. There is no need for selective assembly. Any part of the machine would fit properly in assembly and all similar components are interchangeable.

Skill Reduction: Jigs & Fixtures simplify locating and clamping of the work pieces. Tool guiding elements ensure correct positioning of the tools with respect to the work pieces. There is no need of skillful setting of the work piece or tool. Any average person can be trained to use Jigs & Fixtures. The replacement of a skilled workman with unskilled labor can effect substantial saving in labor cost.

Cost Reduction: Higher production, reduction in scrap, easy assembly and savings in labor costs results in substantial reduction in the cost of work pieces produced with Jigs & Fixtures.

1.6. Materials Used In Fixtures

Jigs and fixtures are made from a variety of materials some of them can be hardened to resist wear. It is sometimes necessary to use non-ferrous metals like Phosphor Bronze or Brass to reduce wear of mating parts or Nylons or Fiber to prevent damage to the work piece.

Mild steel: It is the cheapest and most widely used material in Jigs & Fixtures. It contains less than 0.3%C. Steel En 2 falls in this category. This steel can be case hardened to 56 HRC. It is used to make parts which are not subjected to wear and not highly stressed.

High Tensile Steels: These can be classified into medium carbon steels with 0.45-0.65%C (En 8, En 9) and alloy steels like En 24 (40Ni2Cr1Mo28).The tensile strength can be increased up to 125 kg/mm^2 by tempering.

Medium carbon steels are used widely for fasteners, structural works while HTS are used for high stress applications.

Case Hardening Steels: These can be carburized and case hardened to provide 0.6-1.5 mm thick, hard exterior (58-62 HRC). 17Mn1Cr95 steels with 1%Mn and 0.95%Cr is widely used for locating pins, Rest pads etc. These steels are suitable for parts which require only local hardness on small wearing surfaces.(Ex: En 353, En 36).

Cast Iron: It contains 2-2.5%C. As it can withstand vibrations well, it is used widely in milling fixtures. The ingenious shaping of a casting and the pattern can save a lot of machining time. Nodular CI is as strong as MS while Meehanite castings have heat resistance, wear resistance and corrosion resistance grades.

Nylon and Fiber: These are usually used as soft lining of clamps to prevent denting or damage to work piece under high clamping pressure. Nylon or Fiber pads are screwed or stuck to mild steel clamps.

2. LITERATURE REVIEW

B John J. et al [1] have focused on the design of fixtures for turbine blades is a difficult problem even for experienced toolmakers. Turbine blades are characterized by complex three-dimensional surfaces, high performance materials that are difficult to manufacture, close tolerance finish requirements, and high precision machining accuracy. **A Al-Habaibeh.et al [2] have made an attempt** to an experimental design and evaluation of a pin-type universal clamping system. The clamping system is designed for holding complex-shaped aerospace components, such as turbine blades, during machining processes. **S. Keith Hargrove et al [3]** has addressed many of the micro issues of automating the fixture design process using computers. Most of this research has concentrated on the geometric and kinematic factors that determine the configuration of a computer-aided fixture design (CAFXD) system **Kailing Li Ran Liu et al [4]** discussed about the research and development of the CAD/CAPP/CAM and the wide application of CNC technique in the manufacturing, the traditional method for the jig and fixture design has not adapted to the demands of complexity and variety in the practical production with update of products more and more rapid. **Y. Zheng et al [5]** has presented a systematic finite element model to predict the fixture unit stiffness by introducing nonlinear contact elements on the contact surface between fixture components. The contact element includes three independent springs: two in tangential directions and one in the normal direction of the contact surface. Strong nonlinearity is caused by possible separation and sliding between two fixture components. **G. Padilla at el [6]** have focused on the organization of the different stages of the production cycle in order to shorten the time to market. Within this context, fixture design is crucial: the fixture is the major link between the machined part and the machine tool with a strong influence on the part quality, manufacturing delays and costs. Production process difficulties are focused on the fixture design.

It has been an evident case that the Design of Machining Fixture for Rotor Blade on VMC machine is a research topic of vitality. A thorough study of literature suggests the usage of machining fixture for rotary blades. Fixture Design consists of High product rate, low manufacturing cost operation.

3. FIXTURE DESIGN` FOR TURBINE ROTOR BLADE

For making the machining fixture design it is required to study in detail about the component for which fixture is designed and customer requirements.

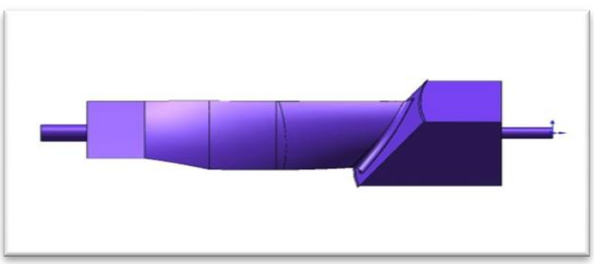
Component Description
The component is Rotor Blade
Component material is Aluminum Alloy
Composition of Aluminum Alloy

1. Silicon
2. Magnesium
3. Manganese
4. Zinc
5. Chromium

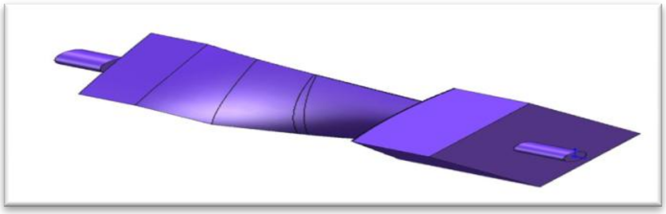
Customer Requirement
The requirement is a machining Fixture.
Single component loading at a time.
Loading and unloading of part using lifting tackles and it shouldn't foul with either machine elements or fixture elements.
Fool proofing while loading component.
Write-up of Interchangeable elements.
Machining Accuracy should be within 50 microns.

3.1 Component & Machine Details

Component : ROTOR BLADE
Material : ALUMINIUM ALLOY
Input Condition : Base Machined
Machine Used : VMC-4AXISTool Taper
: BALL NOSE TOOL
Operation: Face milling, drilling, slot milling.



ROTOR BLADE (A)



ROTOR BLADE (B)

ROTOR BLADE (C)

Fig 3.1

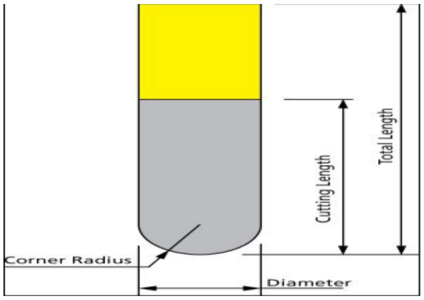
Vertical Machining Centre 4-Axis AS5/A40

Fig 3.2

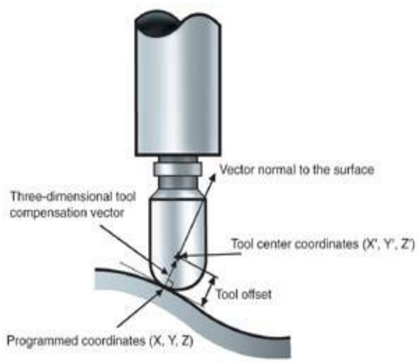
Table 3.1 Vertical Machining Centre 4 Axis AS5/A40

S.No	Parameters	Specifications
1	Pallet Size	600 x 400 mm
2	X Traverse	600 mm
3	Y Traverse	350mm
4	Z Traverse	400 mm
5	Spindle RPM	12,000
6	Rapid Traverse	50 m/min
7	Cutting Feed rate	50 m/min
8	Positional Accuracy	0.025mm
9	Indexing	0.3Sec
10	ATC Capacity	20 Tools
11	Tool to Tool	5 sec
12	Chip to Chip	3.8 sec

13	Power	7Kw
14	Material Removal Rate	1mm
15	Maximum Tool Weight	3.5kg



(a) Cutting Tool (Ball Nose Tool)



(b) Cutting Tool Profile (Ball Nose Tool)

Fig 3.3

Conceptual Layout

Fixture is to be designed for face milling, drilling and taping. The holes are to be drilled on the machined face. Hole sizes and lengths are given in details in operation sheet. So from the nature of the operations to be carried out.

By taking all above factors into considerations, we have generated a conceptual layout of fixture as follows.

1) Part to be loaded on cylindrical pin and Diamond pi the help of Rough Guide pins.
2) Part to be butted against rest pads.
3) Hydraulic swing clamps to be used for clamping.
4) Orientation to be kept always on pre machined hole.
5) Part seat check to be accommodated on rest pads.

3.2 LIST OF OPERATIONS MACHINE:

AS5/A40 VMC-4AXIS MACHINE

VMC-CV&CX Profiles Roughing

After clamping the component in the fixture, the fixture is loaded with help of clamping plug with 0-180 degrees in rotor axis on the machine. first operation is roughing operation is done on vmc -4axis machine with 10diameter ball nose tool on both sides cv and cx profiles for the component convex operation is done with 0-180 degrees ,after convex operation fixture is rotated 0-200 degrees for the concave operation.

Heat Treatment

This operation has to do after roughing operation in this operation component is heated up to 140 degrees centigrade. It will continuously heated up to 45 mints

VMC-CV & CX Profiles Semi Finishing

Semi finishing operation is done after heat treatment on VMC -4axis machine with 8 diameter ball nose tool on both sides cv and cx profiles for the component.

VMC-CV&CX Profiles Finishing

Finishing operation is done after semi finishing operation on vmc -4axis machine with 8diameter ball nose tool on both sides cv and cx profiles

3.3 Procedure for Fixture Design

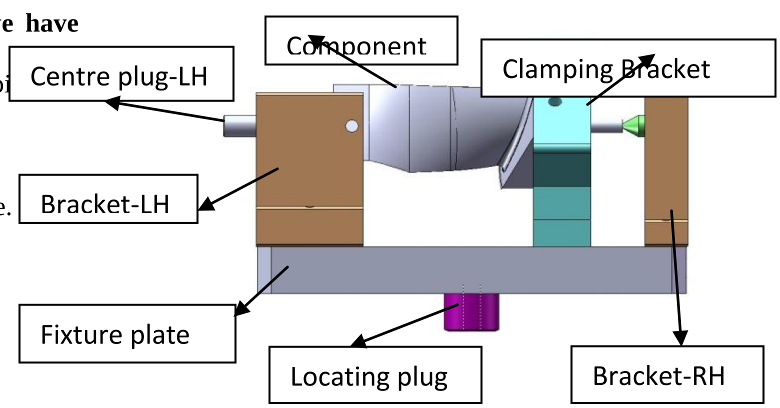
1) Pre-DAP 2) DAP (Design Approval Process)
3) Finalize Layout 4) Detailing
5) Documentation

3.4. MAIN ELEMENTS OF FIXTURE

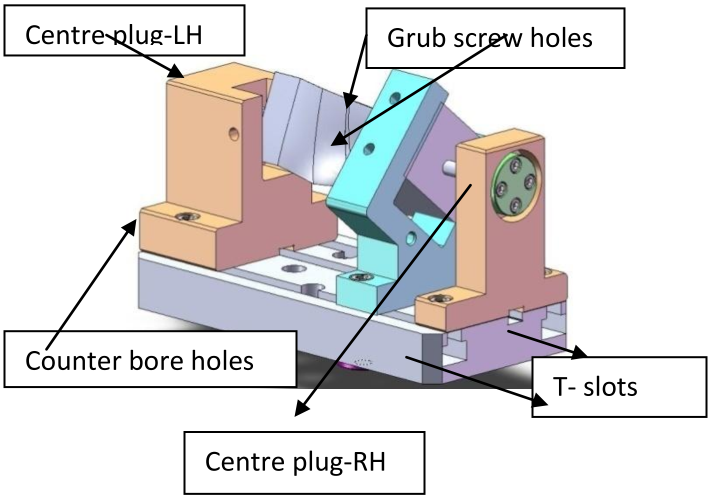
1. Fixture plate 2. Clamping bracket
3. Bracket-LH 4. Bracket-RH
5. Centre plug-RH 6. Centre plug –LH
7. V- block 8. Thumb screw
9. Grub screw 10. Locating plug
11. Support pin, Tenon, Spl T-nut, Hex soc head cap screw.

Fixture Assembly:

This subassembly is made of different parts of which many are standard items used for particular application. The main parts of this assembly are as follows:



(a) Assembly of Fixture with Component (Rotor Blade)



(b) Assembly of Fixture with Component (Rotor Blade)

Fig 3.4

3.5 CALCULATIONS

3.5.1 For CV & CX Profiles Face Milling:

Available Data:
Component Material: Al Alloy
Cutting Tool: Ball nose tool
Cutting Speed = 3000 rpm
Cutter Dia(D) = Ø10 mm
Width of Cut, (b)= 5 mm
No of Teeth, (Z) = 2
Feed(S) = 1000 mm/min

Notations Used:

RPM – Revolutions per Minute
Q – Material Removal Rate,cm^3/min
P – Unit Power, kW/ cm^3/min
T_s – Torque, N-m
S_m – Feed per min, mm/min
P – Spindle Power, kW
S_z - Feed per Tooth, mm/tooth
F_c – Cutting Force, N or kgf

Speed Calculations (v):
V = πDN/1000 m/min = πx10x3000/1000
= 94.24 m/min

Feed/Tooth (Sz):
Sz= S/ZxSpeed = 1000/2x3000
= 0.16 mm/tooth

Feed per minute(Sm):
Sm = Sz x Zx x N = 0.16 x 2 x 3000
= 960 mm/min

Material removal rate(Q):
Q = b x d x Sm / 1000 = 5 x 0.5 x 960
= 2.4 cm3/min
Where b = width of cut
d = depth of cut , Sm = Feed /min.

Unit power:
U = 2.4 kw / cm3 / min
Correction factor for flank wear (Kh): = (1.10-1.25)
Correction factor for radial rake angle (Kr): = 0.87
Radial rake angle: = 20 degrees

Power at the spindle (N):
N = U x Kh x Kr x Q kw
= 2.4 x 1.15 x 0.87 x 2.4 = 6 kw

Power at the motor (Nel):
Nel = N /E = 6/0.8 = 7.5 kw

Tangential cutting force (Pz) :
Pz = 6120 x N / V kgf
Pz = 6120 x 6 / 94.24 = 389.64 = 3818.5 N

Torque at spindle (Ts) :
Ts = 975 x N / n = 975 x 6 / 3000
= 1.95 = 19.1 N-M

Clamping force(F_c):
F_c = 3 x cutting force = 3 x 3818.5
= 11455.5 N

3.5.2 For Slot Milling

Available Data:

Component Material: Al Alloy
Cutting Tool:Ball nose tool
Cutting Speed = 2000 rpm
Cutter Dia(D) = Ø5 mm
Depth of Cut,(d)=0.5 mm
Width of Cut, (b)= 2.5 mm
No of Teeth, (Z) = 2
Feed(S) = 1200 mm/min.

Speed Calculations (v):
V = πDN/1000 = πx5x2000/1000
= 31.41 m/min

Feed/ Tooth (Sz):
Sz = S/ZxSpeed = 1200/2x2000
= 0.3 mm/tooth.

Feed per minute(Sm):
Sm = Sz x Zx x N = 0.3 x 2 x 2000 cm^3
= 1200 mm/min

Material removal rate (Q):

$Q = b \times d \times Sm / 1000\ cm^3/min$

$= 2.5 \times 0.5 \times 1200 = 1.5\ cm3/min$

Where b = width of cut

d = depth of cut, Sm = Feed /min

Unit power(U):

U = 2.4 kw / cm3 / min

Correction factor for flank wear (Kh): = (1.10-1.25)

Correction factor for radial rake angle (Kr): = 0.87

Radial rake angle: = 20 degrees

Power at the spindle (N):

N = U x Kh x Kr x Q = 2.4 x 1.15 x 0.87 x 1.5

= 3.2 kW

Power at the motor (Nel):

Nel = N /E = 3.2/0.8 = 4.11 kw

Tangential cutting force (Pz) :

Pz = 6120 x N / V = 6120 x 3.2 / 31.41

= 623.45 kgf

= 6110.2 N

Torque at spindle (Ts) :

Ts = 975 x N / n = 975 x 3.2/ 2000

= 15.21 N-M.

Clamping force (Fc):

Fc = 3 x cutting force = 3 x 6110.2

=18330.6 N.

3.5.3. For Hole Drilling

Available Data:

Component Material: Al Alloy

Hardness = 190 – 220 BHN

Speed (N) = 1500 rpm

Drill Dia = Ø2.5 mm

Max Drill Depth = 5 mm

Feed per Revolution = 0.04 -0.06 mm/rev

Notations Used:

kW_s – Spindle Power, kW

Tf – Thrust Force, N or kgf

Cutting Speed Calculations(V):

$V = \pi \times D \times N / 1000$ m/min

$= \pi \times 2.5 \times 1500 / 1000 = 11.78$ m/min

Material factor[11]: k = 0.55

Torque:

T = 975 x N/ n = 975 x 0.036 /1500

= 0.0234 kgf = 0.229 N

Spindle Power:

$N = 1.25 \times D^2 \times k \times n\ (0.056 + 1.5 \times s) / 10^5$

$= 1.25 \times (2.5)^2 \times 0.55 \times 1500 \times (0.056 + 1.5 \times 0.04) / 10^5$

= 0.036 kw

Power at the motor :

Rel = N / E kw = 0.036/ 0.8 = 0.045 kw

= 4.5 kw

Thrust Force:

$Tf = 1.16\ K\ D\ (100 \times s)^{0.85}$ kgf

$= 1.16 \times 0.55 \times 2.5 \times (100 \times 0.04)^{0.8}$

= 5.18 kgf = 50.7 N

Clamping force (Fc):

Fc = 3 x cutting force

= 3 x 50.7 = 152.1 N.

3.5.4 For CV& CX profiles finishing milling

Available Data:

Component Material: Al Alloy

Q – Material Removal Rate, cm^3/min

Cutting Speed(N) = 4000 rpm

Dia of cutter(D) = Ø8 mm

Max Depth of cut(d) = 0.2 mm

Feed per Revolution(S) =1000 mm/min

Cutting tool =Ball nose tool

No of teeth (Z) =2

Speed Calculations (v)[11]:

$V = \pi DN/1000$ m/min $= \pi x8x4000/1000$

= 100.53 m/min

Feed/Tooth(Sz):

Sz = S/ZxSpeed = 1000/2x4000

= 0.125 mm/tooth

Feed per minute (Sm):

Sm = Sz x Zx x N mm/min = 0.125 x 2 x 4000

= 1000 mm/min

Material removal rate(Q):

$Q = b \times d \times Sm / 1000\ cm^3/min$

$= 4 \times 0.2 \times 1000 = 0.8\ cm^3/min$

Where, b = width of cut, d = depth of cut

Sm = Feed /min

Unit power:

$U = 2\ kw / cm^3 / min$

Correction factor for flank wear(Kh): = (1.10-1.25)

Correction factor for radial rake angle(Kr): = 0.87, Radial rake angle: = 20 degrees

Power at the spindle (N):

N = U x Kh x Kr x Q kw

= 2.4 x 1.15 x 0.87 x 0.8
= 1.92~2 kw

Power at the motor (Nel):
Nel = N /E = 2/0.8 = 2.5 kw

Tangential cutting force (Pz) :
Pz = 6120 x N / V kgf
= 6120 x 2 / 100.53
= 121.75 kgf = 1193.1 N

Torque at spindle (Ts) :
Ts = 975 x N / n kgf.m
= 975 x 2 / 4000
= 0.4875 kgf.m = 4.77 N-M

Clamping force(Fc):
Fc = 3 x cutting force
= 3 x 1193.1 = 3579.3 N.

3.6 ANALYSIS OF FIXTURE BODY

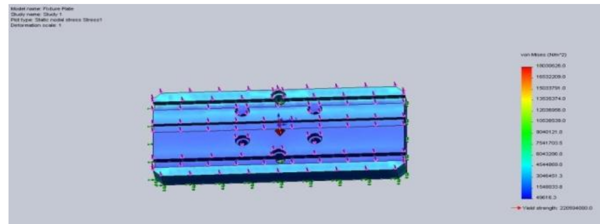
3.6.1 Selection of Fixture Body

The customer is used vertical machining center for the machining of component. So that my concept is to keep the component horizontal to the machine bed. For this purpose, I select Tombstone structure. This structure should withstand the cutting forces applied. This Tombstone dimensions should fall under the work envelope of specific machine and it could accommodate the component and fixture elements. Therefore the dimensions of Tombstone (X, Y) 600 X 400. The width of Tombstone will be decided by the analysis, used as Solid works COSMOS as below. By this analysis, the deflection is came 2 microns at maximum force of drilling (5.18 Kgf) at the centre hole point. This value is within the safe tolerance of customer requirement.

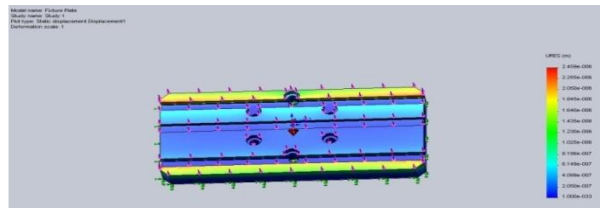
Table.3.2 Fixture plate Study

A) Material properties

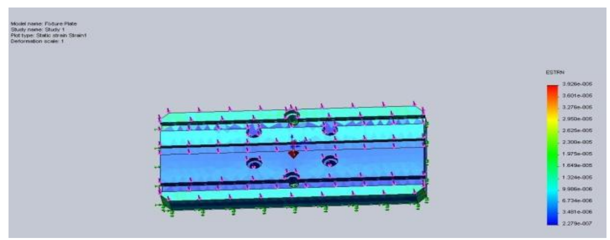
Property Name	Value	Units	Value Type
Elastic modulus	2.1e+011	N/m^2	Constant
Poisson's ratio	0.28	NA	Constant
Shear modulus	7.9e+010	N/m^2	Constant
Mass density	7800	kg/m^3	Constant
Tensile strength	3.9983e+008	N/m^2	Constant
Yield strength	2.2059e+008	N/m^2	Constant
Thermal xpansion coefficient	1.3e-005	/Kelvin	Constant
Thermal conductivity	43	W/(m.K)	Constant
Specific heat	440	J/(kg.K)	Constant



(a) Fixture plate-stress plot



(b) Fixture plate-Displacement plot



(c) Fixture plate-strain plot

Fig.3.13. Fixture plate

Fig.3.13 (a) shows the variation of von mises stress. The max value of von mises stress is (1.80306e+007) and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load. Fig.3.13(b) shows the variation of resultant displacement. The max value of resultant displacement is2.45948e-006m and is developed where there is maximum load.

Fig.3.13 (c) shows the variation of equivalent strain. The max value of equivalent strain is3.92623e-005 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

B). Study Results of Fixture plate

Name	Type	Min	Location	Max	Location
Stress1	VON:von Mises Stress	49616.3 N/m^2 Node: 23474	(-2.29223e-007 mm, -10.5 mm, -23.0048 mm)	1.80306e+007 N/m^2 Node: 16675	(8.74987 mm, 49.9996 mm, -9.50067 mm)
Displacement1	URES: Resultant Displacement	0 m Node: 5	(2.79 mm, -39.8324 mm, -35 mm)	2.45948e-006 m Node: 1577	(150 mm, 44.9983 mm, -0.00174476 mm)
Strain1	ESTRN: Equivalent Strain	2.279e-007 Element: 6917	(-39.9583 mm, 33.8766 mm, -24.449 mm)	3.92623e-005 Element: 6602	(8.55571 mm, 52.7547 mm, -10.1624 mm)

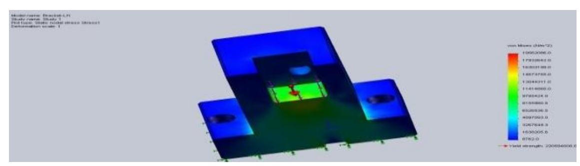
B). Study Results of Bracket-LH

Name	Type	Min	Location	Max	Location
Stress1	VON: von Mises Stress	8761.98 N/m^2 Node: 247	(-41.9997 mm, 114.767 mm, -37.4978 mm)	1.95621e+007 N/m^2 Node: 9307	(7.35617 mm, 4.35072 mm, 37.5001 mm)
Displacement1	URES:Resultant Displacement	0 m Node: 127	(-60 mm, -1.02349e-012 mm, 5.5 mm)	3.32987e-006 m Node: 8924	(-6.9999 mm, 69.7635 mm, 37.5017 mm)
Strain1	ESTRN: Equivalent Strain	2.29337e-008 Element: 2970	(-67.0372 mm,27.5372 mm,-35.4297 mm)	5.8501e-005 Element: 8559	(7.62384 mm, 4.79117 mm,35.1563 mm)

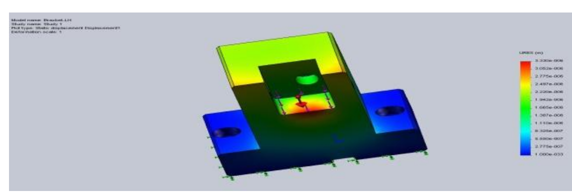
Table.3.3 Bracket-LH-Study

A) Material Properties:

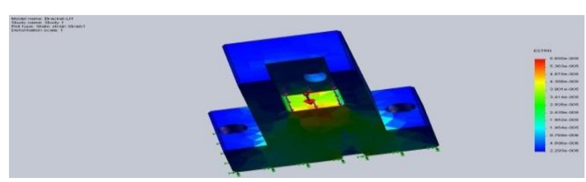
Property Name	Value	Units	Value Type
Elastic modulus	2.1e+011	N/m^2	Constant
Poisson's ratio	0.28	NA	Constant
Shear modulus	7.9e+010	N/m^2	Constant
Mass density	7800	kg/m^3	Constant
Tensile strength	3.9983e+008	N/m^2	Constant
Yield strength	2.2059e+008	N/m^2	Constant
Thermal expansion coefficient	1.3e-005	/Kelvin	Constant
Thermal conductivity	43	W/(m.K)	Constant
Specific heat	440	J/(kg.K)	Constant



(a) Bracket-LH_Von-Mises Stress Plot



(b) Bracket –LH- Displacement Plot



(c) Bracket-LH-Strain Plot

Fig 3.14 Bracket-LH

Fig.3.14 (a) shows the variation of von mises stress. The max value of von mises stress is1.95621e+007 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load. The maximum load developed at the bottom of the bracket-LH.

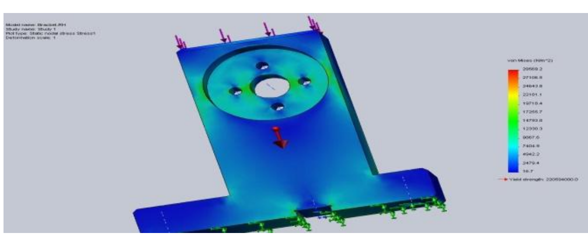
Fig.3.14 (b) shows the variation of resultant displacement. The max value of resultant displacement is3.32987e-006 and is developed where there is maximum load.

Fig.3.14 (c) shows the variation of equivalent strain. The max value of equivalent strain is5.8501e-005 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

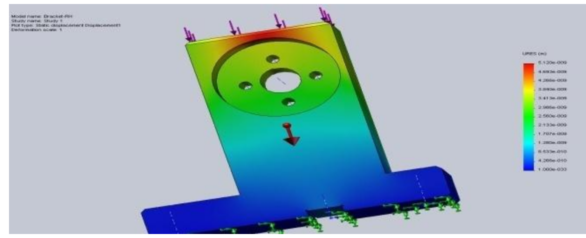
Table 3.4 Bracket-RH-Study

A) Material Properties:

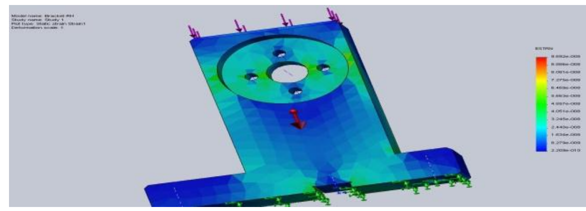
Property Name	Value	Units	Value Type
Elastic modulus	2.1e+011	N/m^2	Constant
Poisson's ratio	0.28	NA	Constant
Shear modulus	7.9e+010	N/m^2	Constant
Mass density	7800	kg/m^3	Constant
Tensile strength	3.9983e+008	N/m^2	Constant
Yield strength	2.2059e+008	N/m^2	Constant
Thermal expansion coefficient	1.3e-005	/Kelvin	Constant
Thermal conductivity	43	W/(m.K)	Constant
Specific heat	440	J/(kg.K)	Constant



(a) Bracket-RH –Stress plot



(b) Bracket-RH-Displacement plot



(c)Bracket-RH strain plot

Fig 3.15 Bracket-RH

Fig.3.15 (a) shows the variation of von mises stress. The max value of von mises stress is29569.2 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load.

Fig.3.15 (b) shows the variation of resultant displacement. The max value of resultant displacement is5.11953e-009 m and is developed where there is maximum load.

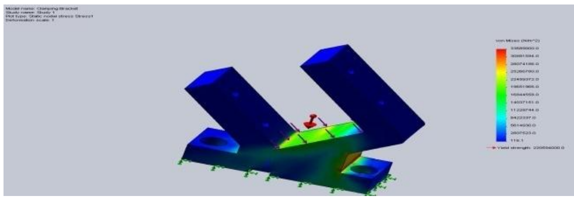
Fig.3.15(c) shows the variation of equivalent strain. The max value of equivalent strain is9.69231e-008 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

Table. 3.5 Clamping Bracket Study

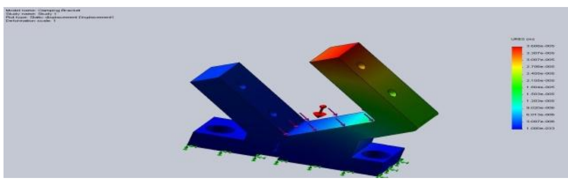
A) Material Properties:

Property Name	Value	Units	Value Type
Elastic modulus	2.1e+011	N/m^2	Constant
Poisson's ratio	0.28	NA	Constant
Shear modulus	7.9e+010	N/m^2	Constant
Mass density	7800	kg/m^3	Constant
Tensile strength	3.9983e+008	N/m^2	Constant
Yield strength	2.2059e+008	N/m^2	Constant
Thermal expansion	1.3e-005	/Kelvin	Constant

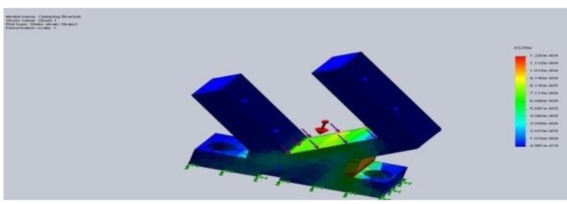
coefficient			
Thermal conductivity	43	W/(m.K)	Constant
Specific heat	440	J/(kg.K)	Constant



(a) Clamping Bracket Stress plot



(b) Clamping Bracket-Displacement plot



(C)Clamping Bracket-strain plot

Fig 3.16 Clamping Bracket

Fig.3.16 (a) shows the variation of von mises stress. The max value of von mises stress is3.3689e+007 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load. The blade right side is clamped using clamping bracket. The maximum load developed in downward direction.

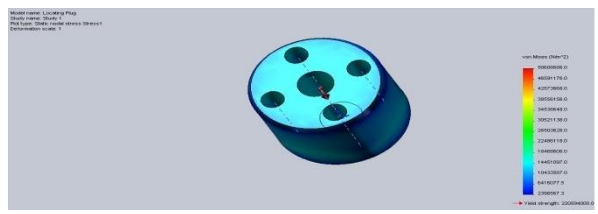
Fig.3.16 (b) shows the variation of resultant displacement. The max value of resultant displacement is 3.60786e-005 m and is developed where there is maximum load.

Fig.3.16 (c) shows the variation of equivalent strain. The max value of equivalent strain is 0.00012195 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

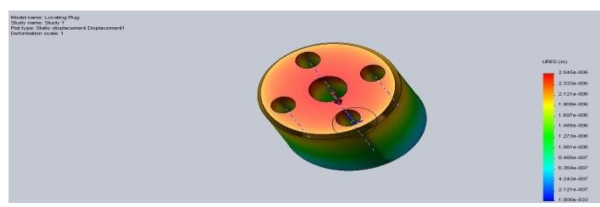
Table 3.6 Locating plug Study

A) Material Properties

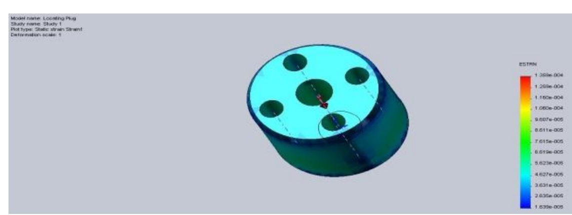
Property Name	Value	Units	Value Type
Elastic modulus	2.1e+011	N/m^2	Constant
Poisson's ratio	0.28	NA	Constant
Shear modulus	7.9e+010	N/m^2	Constant
Mass density	7800	kg/m^3	Constant
Tensile strength	3.9983e+008	N/m^2	Constant
Yield strength	2.2059e+008	N/m^2	Constant
Thermal exp.coefficient	1.3e-005	/Kelvin	Constant
Thermal conductivity	43	W/(m.K)	Constant
Specific heat	440	J/(kg.K)	Constant



(a) Locating Plug-Stress plot



(b) Locating Plug-Displacement plot



(c) Locating Plug Strain plot

Fig 3.17 Locating Plug

The total stresses depend on locating plug. Because the chuck is holding the clamping plug. Fig.3.17 (a) shows the variation of von mises stress. The max value of von mises stress is5.06087e+007 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load.

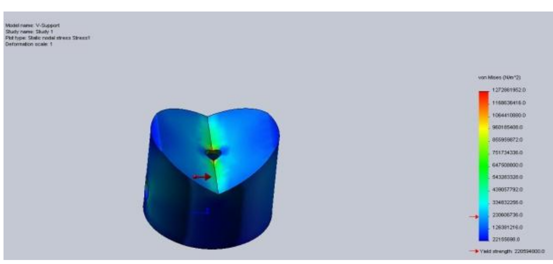
Fig.3.17 (b) shows the variation of resultant displacement. The max value of resultant displacement is 2.54541e-006 m and is developed where there is maximum load.

Fig.3.17 (c) shows the variation of equivalent strain. The max value of equivalent strain is 0.000135903 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

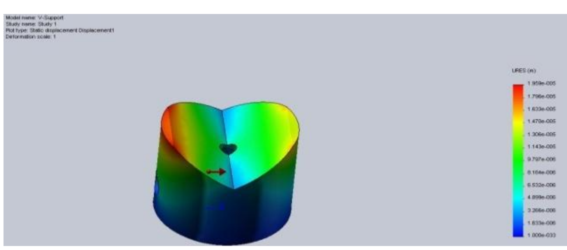
Table 3.7. V-Block Study

A) **Material Properties**

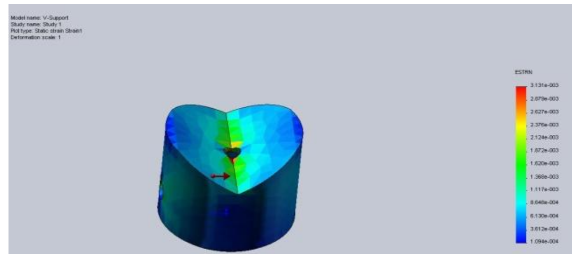
Property Name	Value	Units	Value Type
Elastic modulus	2.1e+011	N/m^2	Constant
Poisson's ratio	0.28	NA	Constant
Shear modulus	7.9e+010	N/m^2	Constant
Mass density	7800	kg/m^3	Constant
Tensile strength	3.9983e+008	N/m^2	Constant
Yield strength	2.2059e+008	N/m^2	Constant
Thermal exp. coefficient	1.3e-005	/Kelvin	Constant
Thermal conductivity	43	W/(m.K)	Constant
Specific heat	440	J/(kg.K)	Constant



(a) Support Stress plot



(b) V-Support Displacement plot



(c) V-Support-Strain plot

Fig 3.18 V-Support

Fig.3.18 (a) shows the variation of von mises stress. The max value of von mises stress is1.27286e+009 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load. The load developed from left to right of the V-Block.

Fig.3.18 (b) shows the variation of resultant displacement. The max value of resultant displacement is 1.95946e-005 m and is developed where there is maximum load.

Fig.3.18 (c) shows the variation of equivalent strain. The max value of equivalent strain is 0.00313094 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

The above results show the Design of Machining fixture for Rotor blade on VMC machine. The main aim of the fixture is to reduce the lead time, High product rate and low manufacturing cost.

3.6.2 Features of Fixture Assembly

1) **Machining fixture:**
Machining fixture are used for quick operations to perform actions such as butting the component against pads, clamping and orientation of the part. It saves loading time since many actions are performed simultaneously.It ensures proper clamping and butting against locating pads due to use of hydraulic supports and clamps.

2) **Repeatability and accuracy of loading and hence operations to be performed**

3) **Fool proofing** Ensures the part is always loaded in correct position

4) **Reduction in cycle time** Due to use of hydraulic elements, automatic loading tackles, and HMC the cycle time is reduced to a large extent.

5) **Longer life of fixture assembly** Long life of the fixture is ensured due to the use of changeable parts in case of wear and strength of the parts is also ensured by the use of rigid plates and castings.

6) **Cost Effectiveness** Since the cycle time is reduced, the cost per piece is also reduced.

7)Manufacturing feasibility The parts are designed by considering the manufacturing possibilities and also form the point of mfg costs of the parts.

8)Use of Standard parts Standard parts are used wherever possible and hence lead time is reduce

B) Study Results of Bracket-RH

Name	Type	Min	Location	Max	Location
Stress1	VON: von Mises Stress	16.7346 N/m^2 Node: 12786	(-68 mm,20mm, -12.3438 mm)	29569.2 N/m^2 Node: 12946	(7.3594 mm, 4.35443 mm,-12.5 mm)
Displacement1	URES: Resultant Displacement	0 m Node: 211	(-60 mm,-1.02002e -012 mm,5.5 mm)	5.11953e-009 m Node: 13966	(1.45362 mm, 114.958mm,15 mm)
Strain1	ESTRN: Equivalent Strain	2.20901e-010 Element: 369	(-67.1043 mm, 19.6489 mm, -6.52443 mm)	9.69231e-008 Element: 2661	(7.83594 mm, 4.61988 mm, -11.9517 mm)

B). Study Results of Clamping Bracket

Name	Type	Min	Location	Max	Location
Stress1	VON: von Mises Stress	116.104 N/m^2 Node: 11815	(1.66621 mm, 139.405mm,-1.39032 mm)	3.3689e+007 N/m^2 Node: 10510	(-11.6668mm,19.1233 mm, -49.0009 mm)
Displacement1	URES: Resultant Displacement	0 m Node: 178	(0 mm, -4 mm, 43.5 mm)	3.60786e-005 m Node: 289	(-25.0003mm,150.114 mm,-14.1611 mm)
Strain1	ESTRN: Equivalent Strain	4.98094e-010 Element: 9565	(-22.258 mm,147.077 mm,-4.8263mm)	0.00012195 Element: 8765	(-7.53101 mm, 17.8654 mm,-47.935 mm,

B). Study Results of Locating Plug

Name	Type	Min	Location	Max	Location
Stress1	VON: von Mises Stress	2.39857e+006 N/m^2 Node: 222	(-16.3002 mm, -3.32448e-007 mm, 10.11 mm)	5.06087e+007 /m^2 Node: 347	(-4.22822 mm, -16.5174 mm, 0 mm)
Displacement1	URES: Resultant Displacement	0 m Node: 6	(3.05 mm,-5.28276 mm,0 mm)	2.54541e-006 m Node: 11839	(3.60625mm,-3.60624 mm,34.9975 mm)
Strain1	ESTRN: Equivalent Strain	1.63942e-005 Element: 3964	(-0.333289 mm, 16.8188 mm, 9.87042 mm)	0.000135903 Element: 1897	(16.6995 mm, 4.88732 mm, 0.871527 mm)

B). Study Results of V-Support

Name	Type	Min	Location	Max	Location
Stress1	VON: von Mises Stress	2.21557e+007 N/m^2 Node: 6270	(6.13578 mm, 2.99703 mm, 0.173526 mm)	1.27286e+009 /m^2 Node: 103	(9.99417 mm, 0.000837307 mm, 0.999628 mm)
Displacement1	URES: Resultant Displacement	0 m Node: 35	(0 mm,-3.09808 mm, -1.78868 mm)	1.95946e-005 m Node: 242	(13.9865 mm, 6.94412 mm,3.99821 mm)
Strain1	ESTRN: Equivalent Strain	0.000109444 Element: 2572	(2.74185 mm,3.49539 mm,0.260865 m)	0.00313094 Element: 741	(9.96304 mm,0.328087 mm,1.24376 mm)

4. RESULTS AND DISCUSSION

In the present work, the analysis of fixture is carried out using Solid works COSMOS. The geometric model of the Fixture elements is drawn by using AutoCAD. The fixture is loaded with the help of clamping plug with 0-180^0 in rotor axis on the machine.First operation is roughing operation, is done on vmc -4axis machine with 10diameter ball nose tool on both sides cv and cx profiles. For the component convex operation is done with 0-180 degrees, after convex operation fixture is rotated 0-200 degrees for the concave operation.Semi finishing operation is done after heat treatment on VMC -4axis machine with 8 diameter ball nose tool on both sides cv and cx profiles for the component.Finishing operation is done after semi finishing operation on vmc -4axis machine with 8diameter ball nose tool on both sides cv and cx profilesSo, all the operations are carried out by using same fixture at different control conditions. At ought milling operation the material removal rate is high. so at that time max stress is developed on fixture. In finishing operation material removal rate is less so stress developed at that time less The fixture is developed at max load condition and min load condition. The values are calculated to design the fixture using Solid works COSMOS analysis tool, to find out the stress, strain and displacement for each and every component of the fixture assembly. These results are

Case 1:
Figure 3.13 (a) shows the variation of von mises stress. The max value of von mises stress is (1.80306e+007) and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load.
Figure 3.13 (b) shows the variation of resultant displaement.The max value of resultant displacement is2.45948e-006m and is developed where there is maximum load.
Figure 3.13 (c) shows the variation of equivalent strain. The max value of equivalent strain is3.92623e-005 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

Case 2:
Figure 3.14 (a) shows the variation of von mises stress. The max value of von mises stress is1.95621e+007 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load. The maximum load developed at the bottom of the bracket-LH.
Figure 3.14 (b) shows the variation of resultant displaement.The max value of resultant displacement is3.32987e-006 and is developed where there is maximum load.
Figure 3.14 (c) shows the variation of equivalent strain. The max value of equivalent strain is5.8501e-005 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

Case 3:
Figure 3.15 (a) shows the variation of von mises stress. The max value of von mises stress is29569.2 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load.
Figure 3.15 (b) shows the variation of resultant displaement.The max value of resultant displacement is5.11953e-009 m and is developed where there is maximum load.
Figure 3.15 (c) shows the variation of equivalent strain. The max value of equivalent strain is9.69231e-008 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

Case4:
Figure 3.16 (a) shows the variation of von mises stress. The max value of von mises stress is3.3689e+007 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load. The blade right side is clamped using clamping bracket. The maximum load developed in downward direction.
Figure 3.16 (b) shows the variation of resultant displaement.The max value of resultant displacement is 3.60786e-005 m and is developed where there is maximum load.

Figure 3.16 (c) shows the variation of equivalent strain. The max value of equivalent strain is 0.00012195 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

Case5:
The total stresses depend on locating plug. Because the chuck is holding the clamping plug. Figure 3.17 (a) shows the variation of von mises stress. The max value of von mises stress is5.06087e+007 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load.
Figure 3.17 (b) shows the variation of resultant displaement.The max value of resultant displacement is 2.54541e-006 m and is developed where there is maximum load.
Figure 3.17 (c) shows the variation of equivalent strain. The max value of equivalent strain is 0.000135903 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.

Case6:
Figure 3.18 (a) shows the variation of von mises stress. The max value of von mises stress is1.27286e+009 and is developed where there is maximum load. The value of von mises stress is less, where there is minimum load. The load developed from left to right of the V-Block.
Figure 3.18 (b) shows the variation of resultant displacement. The max value of resultant displacement is 1.95946e-005 m and is developed where there is maximum load.
Figure 3.18 (c) shows the variation of equivalent strain. The max value of equivalent strain is 0.00313094 and is developed where there is maximum load. The value of equivalent strain is less, where there is minimum load.
The above results show the Design of Machining fixture for Rotor blade on VMC machine. The main aim of the fixture is to reduce the lead time, High product rate and low manufacturing cost.

5. CONCLUSIONS

The fixture is successfully designed and manufactured at SRI VENKATESWARA MECHANICAL AND ELECTRICAL ENGINEERING INDUSTRIES, private limited, leading manufacturers of earth moving equipment. The following are the results obtained while designing and from tryout of the fixture.

The main purpose of fixture is to locate the work quickly and accurately, support it properly and hold it securely, thereby ensuring the all parts produced in same fixture will come within specified limits.

Another important aspect in designing the fixture is to reduce non production time i.e. setup time. In the designed fixture there is 50% reduction in setup time than previous fixture setup.

Operator conformability has prime consideration in fixture design. In this fixture design ergonomic aspects have studied carefully reducing operator fatigue to minimum.

Rigid clamping and proper loading sequence has achieved the total assembly accuracy within prescribed limit.

The self alignment of components has achieved by designed loading sequence.

Unloading of finished component has achieved successfully without any hindrance of designed groups.

REFERENCES

[1]. BAUSCH John J "Turbine blade fixture design using kinematic Methods and Genetic Algorithms", SPIE Publisher, 2000-11-06, USA.
[2]. A Al-Habaibeh Proceeding of the institution of Mechanical Engineers, Part B: journal of Engineering Manufacture, Sage Publications, volume 217,Number 12/2003.
[3]. S. Keith Hargrove," A systems approach to fixture planning and design" The international Journal of Advanced manufacturing Technology, Volume 10, Number 3, 169-182, DOI: 10.1007/BF01179345.
[4]. Kailing Li Ran Liu Guiheng Bai, "Development of an intelligent jig and fixture design system", Computer-Aided Industrial Design and Conceptual Design, 2006. CAIDCD '06.pp 1-5.
[5]. Y. Zheng, Y. Rong and Z. Hou, "The study of fixture stiffness part I: a finite element analysis for stiffness of fixture units", The international Journal ofAdvanced manufacturing echnology, Volume 36, Numbers 9-10, 865-876, DOI: 10.1007/s00170-006-0908-5
[6]. Yan Zhuang Goldberg, K. "Design rule for tolerance-insensitive and multi-purpose fixtures", Advanced Robotics, 1997.ICAR'97.pp. 681 – 686
[7]. Caillaud, E. Noyes, D. Anglerot, G. Padilla, P. Centre Tech. des Ind. Mecaniques, Senlis (10-13 Oct 1995), "Concurrent engineering: an expert system for fixture design", International Journal of Emerging Technologies and Factory Automation,vol.1, pp.137- 144(23)
[8]. J.F. Melkote Effect of Fixture design variables on fixture-workpiece conformability and Static stability, "Advanced Intelligent Mechatronics", 2001, Volume 1, Como
[9]. Frank W.Wilson, "Hand book of fixture design", Society of Manufacturing Engineers, Tata McGraw Hill, 1997.
[10]. Hiram E. Grant, "Jigs and Fixtures", Tata McGraw Hill, 1967, New York.