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# Design of Jig for cycle time reduction and productivity escalation of railway pinion oil hole drilling.

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***Abstract:*** *In industry the general caters the overall range of products to fulfill themarket needs. To overcome the ever-increasing production demands the industry impliesvarious techniques. As per the company's current requirement they need a technique fordrilling two holes on a Railway Pinion so as to increase the production, improve thequality of product and reduce the operation time. This research aims to design the Jig andFixture. 3D model of the components is made using CATIA V5-R21 software. Thecomponents which undergo specific deformation and stresses are studied using softwareHyper Mesh13.0.Thedesigndrawingsofeachpart are createdby using AutoCADsoftware. According to the dimensions, all the parts are manufactured and assembled totestitsperformance.*

***Keywords–Design, Drill Jig, Static Structural Analysis, Stress, Deformation, Railway Pinion.***

## I. INTRODUCTION

In this section, the pinion is studied for dimensions, appropriate material is selectedfor the manufacturing of Jig, 3D and 2D modeling isdone using suitable softwareanddesignanalysisiscarriedoutforsafetypurpose.

The successful designing of a jig and fixture depends upon the analysis of several factors such as:

- Study of the component
- Study of the type and capacity of the machine
- Study of loading and unloading arrangement
- Study of clamping arrangement
- Study of power devices for operating the clamping elements
- Study of clearance required between the jig and the component
- Study of the tool guiding and the cutter elements
- Study of the ejecting devices
- Study of rigidity and vibration problem
- Study of table fixing arrangement
- Study of methods of manufacture of the jig base, body or frame

**Problem Statement:**

- To design and analyses a 'Jig' for drilling two holes of 4mmdiameter 180º apart on the circumference for the proper flow of lubricant in thegear. simplified and also the time required must get reduced.
- To design a Jig.
- To analyze the major components in the assembly in the Analysis software and compare the results with the hand calculated one.
- To test the manufactured drill Jig and to commission it after tests.

**Methodology-:**

The main objective of the research is to provide a suitable locating and clampingmethod for a drill Jig. The Φ4 mm drill is present in the 6 mm grooves which are to be opened in the Gun drills provided on the face of the Pinion.The main difficultyliesinlocatingtheGundrillrespectivetotheirdrillssincethelengthofGundrillsisnotsame.Themethodusedwhiledesigningadrill Jig assemblyisgivenbelow:

- The research starts by observing and studying the shape and dimensions of the railway pinion.
- Study of various Jigs available in the industry was carried out.
- Based on the shape and dimensions of the railway pinion suitable location and clamping devices are provided.
- Accordingly, the forces are calculated for the exact dimensions of the components in the drill Jig.
- Successively the CAD models were made on CATIA V5-R21 and an assembly was done.
- The major components were studied for deformation and stresses using Analysis Software.
- Approximate cost estimation was carried out and compared with the one given by the vendor.
- Manufacturing and prove out was done carefully.
- A detailed Time-Study was carried out.

## LITERATURE SURVEY

Niraw Newar et. al. [1] carried out a detailed analysis of a drill Jig. They carried outstrength calculations using software like ANSYS and also the natural frequencies wereachieved for various loads ranging from 2000N to 10000N. They also studied for totaldeformation of component under drill thrust, equivalent stresses occurring in component,static force analysis.Firstly, this modelling involved of individual parts of DrillJigassembly and by using part module of CATIA V5-R21. In the assembly module all theindividualcomponentsareimportedandassembled.Secondly,themechanismisshownin the DMU Kinematics module. Finally, the modal and static structural analysis is doneat different loading conditions on the Drill Jig by using ANSYS 14.0. This paper is usedasareferenceforstructuralanalysisofJigandFixturedesignedintheproject.

Shivanand Vathare et. al. [2] designed a drill Jig for cylinder head and cover of theactuator. The drill Jig provides interchangeability to head and cover parts. They studiedstress, strain and deformation of clamp plates, locating pins and concluded whether theywere in allowable limits or not. The paper aptly mentions the number of challenges theindustriesfacenowadaystoincreasetheirproductionratewithgoodqualityandaccuracy. Hence, the time required for production a component must be reduced to assmall as possible. Therefore, this study aims to design a Drill Jig. The main purpose ofmaking this Drill Jig is to perform drilling operation without any need of shifting theworkpiece regularly. Detailed procedure of designing a Drill Jig for head and cover partofacylinderactuatorisexplainedinthisresearchpaper.

P. H. Joshi is the author of the book “Jigs and Fixtures-Design Manual”,2nd Edition.(Print- 2010) [3]. The book is used in the manufacturing industry for standard designprocedures of many types of Jig and Fixtures like drilling jigs, milling fixtures, turningfixtures, grinding fixtures, broaching fixtures, welding and assembly fixtures, etc. Thebook has standard formulae and design data which is used for designing appropriate JigandFixtureaccordingtotheoperationalrequirement.Alsothebookmentionstheestimating procedure for the Jig and Fixture assembly which takes into account variousparameters like material costs, machining costs, heat treatment expenses, assembling andtry-outcosts,etc.

PSG’s Design Data Book (2010 Edition) [4] is a source of standards and codes for thedesigning procedure used in the industry. The book contains information about physicalandchemicalproperties ofmaterials,various compositionsofsteel,heattreatmenttheory,fits and tolerances, standards for rolling elements, etc. The book also covers the topicslike casting, welding, machining calculations, metal forming processes, etc. The bookproves very beneficial in this project of designing the jig and Fixture for the RailwayPinion.

V. B. Bhandari is the author of Design of Machine Elements, 3rd Edition (Print-2015).[5]Thebookisasourceofinformationaboutengineeringmaterials,manufacturingconsiderations in design, design against static load, power screw, spring elements, failureanalysis in components, threaded joints, etc. The book proves beneficial while designinganymachinecomponents.

## II. Design Of Jig

**Work Piece Study**

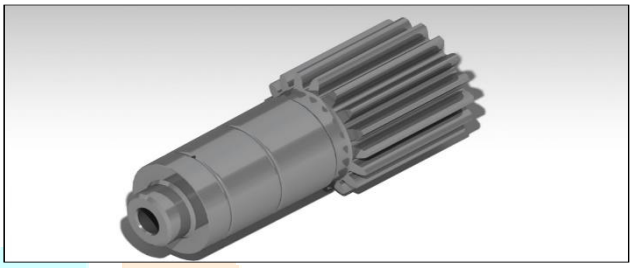

**Fig 1 3D Model of Work-piece**

The work-piece under the project is the Pinion used in Indian Railways' transmission system. The tapered section attached to the gear section is press fitted inside a tapered portion. Thus, it maintains the rigidity of the system and transmits power without any hindrances. After some time, the pinion needs to be taken out for timely maintenance. The pinion has 2 Gun Drills of 6mm diameter as shown in fig. 6. These drills are used to pass pressurized fluid in the tapered section.The drills carry the fluid to their end and the 4mm holes (which we intend to drill), introduce the fluid over the circumference of the tapered section. It creates a pressurized film over the periphery of the section. This function allows the pinion to be easily get removed from the system.

**Cross-SectionalViewofwork-piece**

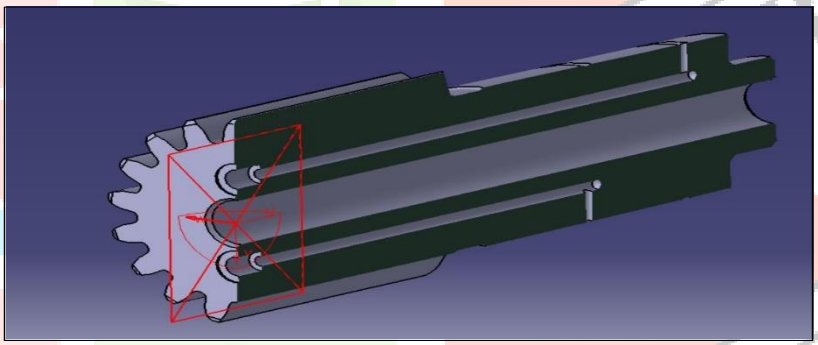

**Fig 2 Cross-SectionalViewofwork-piece**

**Work-piece Details:**

1. PCD of Pinion: - 110.5mm
2. Material: - 18CrNiMo7-6/ En 10084
3. Approximate Weight: - 18.7kg
4. Tapered Section: - Diameter-97.617mm Length-200mm Taper- 1:50
5. Overall Dimensions: - Diameter-110.5mm Length- 328.1mm

The first and the basic process in manufacturing of any product is selection of rawmaterial. The material selected for manufacturingofJig assembly is Mild Steel.En36andEn31isselectedforsomesmallcomponentsduetoitshighstrengthproperty. ManufacturingProcess ofIndividualcomponents.

**Quality Principle:**

The working environment has various processes going on at a single point of time simultaneously. To organize these processes some Quality Principles are adopted viz. 5S, Poka - Yoke, Kaizen, etc. The prominent principle used while designing the Jig assembly is Poka - Yoke.

Poka - Yoke is a quality tool that helps an equipment operator to avoid mistakes and complete the job with minimum errors. In simple words, it is a technique for avoiding simple human error in the workplace. Use of Poka - Yoke can be understood by few examples explained below.

- After due time the Jig plate gets loosened in the hinge and tends to move which leads to errors. Provision of Quarter Turn Screw on the Jig plate allows the operator to restrict the motion of Jig plate about its hinge and the rest plate. It also leads to deletion of errors caused by the same.
- The pinion is to be rotated 180º after the first drill operation. Achieving the exact position is difficult and can be obtained by using extra provisions if provided. In our design, use of locating pin is done which is to be inserted in one of the Gun drills. Locating of the appropriate Gun drill allows to properly drilling the Φ4mm hole without any errors.
- The Pinion location needs to be judged by the reference of some element in the Jig. 5-Rest buttons are provided on the face of the bracket on which the pinion face rests. The height block placement is then referenced from the rest button face. This allows to properly locating the drill position.

Following are the advantages of use of Quality Principle like Poka - Yoke:

- It reduces set-up errors and time required for it.
- It lowers the skill requirements of laborers and increases production flexibility.
- It increases safety of the operator.
- Use of the principle reduces the cost of production.
- Eventually it increases the quality and also the productivity.

**Design Of 3D Model Components**

Base Plate:

- 1)The raw material used for Base plate is Mild steel.
- 2)Milling operation on raw material slab of dimension 525*260*43mm is done to get required dimension of 515*250*33mm according to design.
- 3)Then grinding operation on Base plate is carried out to remove extra material.
- 4)According to the design, required dowel holes are drilled and boring operation is also done.

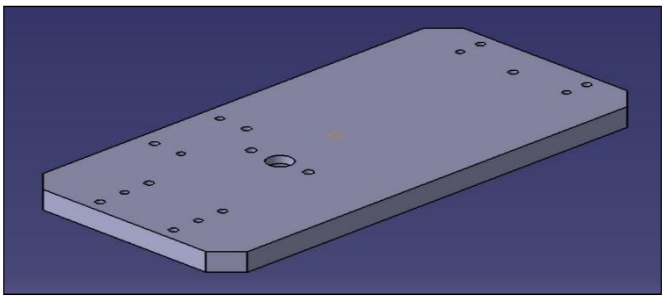

**Fig 3 Base Plate**

**Bracket:**

1)Milling operation on raw material slab of dimension 210*120*120mm is done to get required dimension according to design.

2)All the parts of Bracket were separately milled and then welded according to the design.

3)After welding, milling and surface grinding is done to get final dimension of 200*110*90mm.

4)According to the design, required holes are drilled and boring operation is also done.

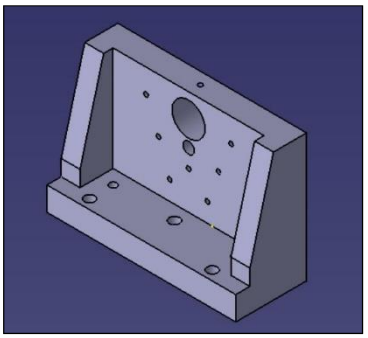

**Fig 4 Bracket**

**Height Block:**

1)The raw material used for Height block is Mild steel.

2)Milling operation on raw material block of dimension 165*110*70mm is done to get required dimension according to design.

3)All the parts of Height block are separately milled and then welded according to the design.

4)After welding, milling and surface grinding is done to get final dimension of 155*100*60mm.

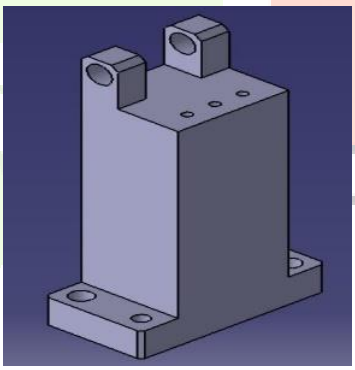

**Fig 5 Height Block**

**Housing:**

1) The raw material used for Housing is Mild steel.
2) Milling operation on raw material block of dimension 150*110*90mm is done to get required dimension according to design.
3) Then welding of all the parts is carried out according to the design.
4) After welding, milling and surface grinding is done to get final dimension.
5) According to the design, required holes are drilled and boring operation is also done.
6) Tapping operation is done for forming internal hole threads of M42 specifications.
7) Finally grinding operation is done to get required dimension of 140*100*80mm.

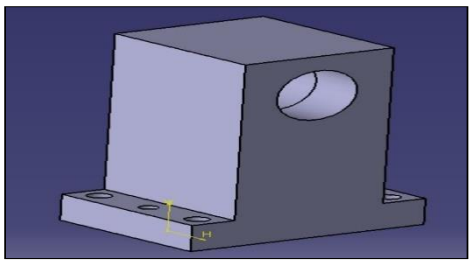

**Fig 6 Height Block**

**Locating Pin-**

1)The raw material used for Locating pin is En36.

2)Using saw machine a 95mm diameter rod is cut for a length of 35mm .

3) Turning operation is carried out on the rod of raw material and reduced to 85mm diameter.

4) Facing operation is done on both the faces of pin to achieve the length of 30mm.

5) To get required hardness, the turned rod is then sent to Case hardening and hardness of 50RC is obtained.

6) Milling is used to create a keyway of length 28mm and circular ends of radius 7mm.

7) Finally grinding operation is done to get required dimension.

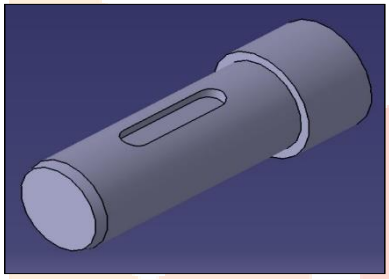

**Fig 7 Locating Pin**

**Fouling pin:**

1) The raw material used for Fouling pin is En36.

2) Using saw machine a rod of 13mm diameter and length 110mm is cut.

3) First of all turning operation is carried out on the rod of raw material having dimensions D13*110mm.

4) To get required hardness, the turned rod is then sent to Case hardening and 55RC is achieved.

5) Chamfering operation with dimensions 1mm*45º is done on the front end of the pin.

6) Knurling operation is done for gripping area on the circumference of the Fouling Pin.

7) Finally grinding operation is done to get required dimension.

8) A chain of length 200mm is attached to the back end of the pin for safekeeping purpose.

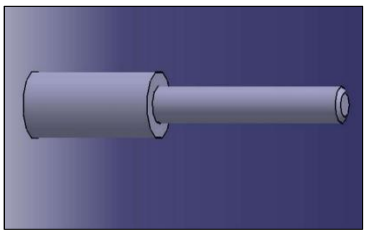

**Fig 8 Fouling Pin**

**Drill Bush:**

1) The raw material used for Drill bush is En31.
2) First of all turning operation is carried out on a rod of raw material having dimensions 16mm diameter and 14mm length.
3) According to the design, required holes of 4mm diameter are drilled and boring operation is also done.
4) Grinding operation is done to get required dimension of 13mm diameter and 13mm length.

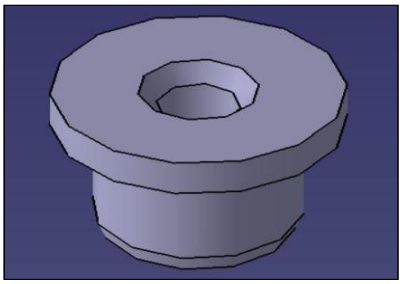

**Fig 9 Drill Bush**

**Center pin**

1)The raw material used for Center pin is En36

2)Using saw machine a rod of 70mm diameter and 160mm length is cut.

3)First of all turning operation is carried out on a rod of raw material and diameter is lowered to 60mm.

4)2 rods of 8mm diameter and 50mm length is fitted in the back end of pin for gripping and rotating purpose

5)Threading operation is carried out on the pin's front end.

6)Knurling operation is done for gripping area on the circumference of the Handle at the back end of Center Pin.

7)To get required hardness, the Center Pin is then sent to Case hardening 55RC

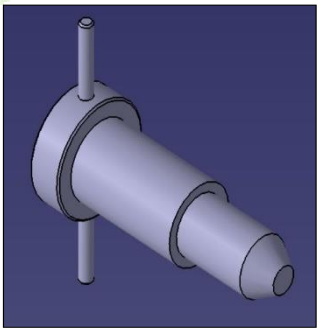

**Fig 10 Drill Bush**

**Jig plate:**

1)The raw material used for Jig plate is Mild steel.
2)Milling operation on raw material slab of dimension 130*90*25mm is done to get required dimension according to design.
3)According to the design, required holes are drilled and boring operation is also done.
4)Finally grinding operation is done to get required dimension of 125*80*20mm.

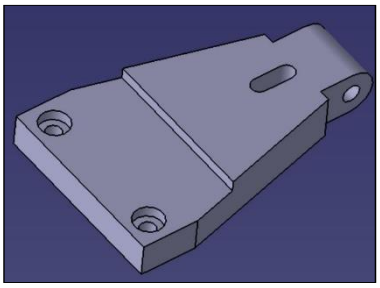

**Fig 11 Drill Bush**

**Rest Button:**

1)The raw material used for Rest button is En31.

2)First of all turning operation is carried out on a rod of raw material having dimensions 22mm diameter and 55mm length.

3)Using Saw machine the turned rod is cut into 5 identical pieces of thickness 10.2mm.

4)Then a counter bore was created in each of the Rest buttons.

5)To get required hardness, the Rest buttons are then sent to Case hardening to achieve 60RC.

6)Finally grinding operation is done to get required dimension of 10mm.

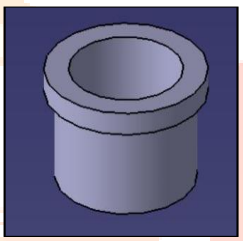

**Fig 12 Rest Button**

**Liner:**

1) The raw material used for Liners is En31.
2) First of all turning operation is carried out on a rod of raw material.
3) For various liner dimensions, rods of 43mm, 15mm, 16mm and 40mm diameter are cut for suitable lengths.
4) Grinding operation is done to get required dimension.

To get required hardness, the Liners are then sent to Case hardening and a hardness

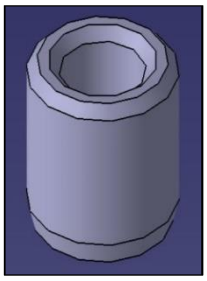

**Fig 13 Liner**

**V-block:**

1)The raw material used for V Block is Mild steel.

2)Milling operation on raw material block of dimension 100*55*40mm is done to get required dimension according to design.

3)Then required holes are drilled and boring operation is also done.

4)Finally grinding operation is done to get required dimension of 90*47*30mm.

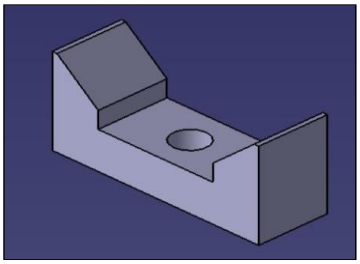

**Fig 14 V-Block**

**Final Design:**

All the components designed for the Jig assembly is done keeping in mind the space constraints. The only concern for the obtained design is 'Cost Saving' which can be achieved by using minimum material. Major components are designed using the analysis done on the HyperMesh software. Numerous permutations of dimensions were carried out and finalized on the basis of force analysis, cost and dimensional constraints.

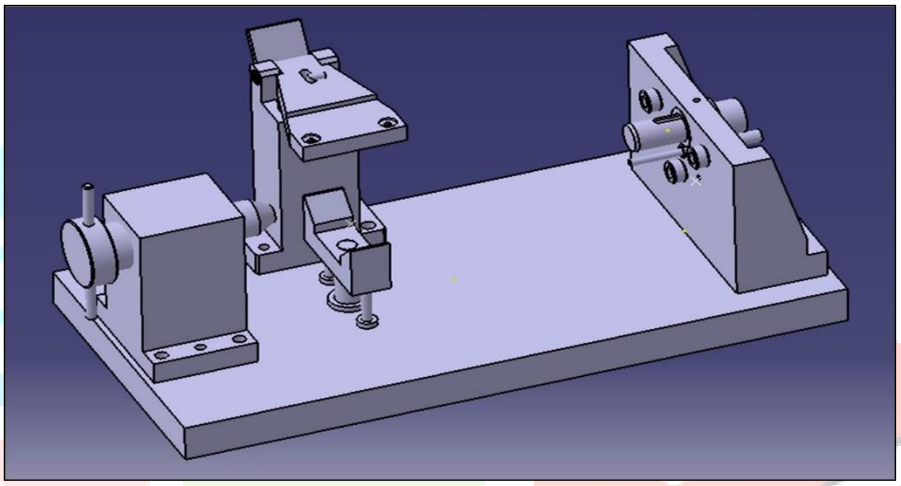

**Fig 15 Final Design**

**DESIGN ANALYSIS**

Any design is not foolproof until it is validated. Our design is validated by use of CAEsoftwareHyper Mesh13.0.We haveperformedstaticstructural analysisonthemodel.

**Meshing:**

Very firstste pin Analysis is meshing, which means discretization. The componentisdividedintofinitenumberofsmallelements.Thishelpsinconvertingtheproblem with infinite DOF's into finite DOF's. With the use of Hyper Mesh 13.0meshingoperationisdoneonBracketandCenterPin.

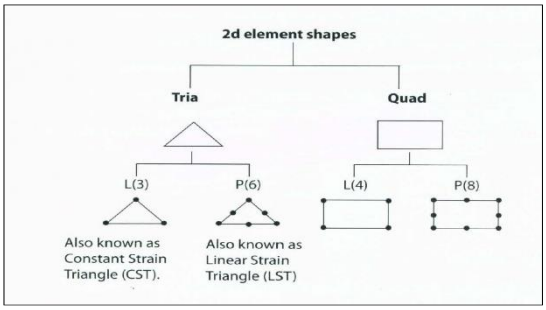


**Fig 16 Typesof2Delements**

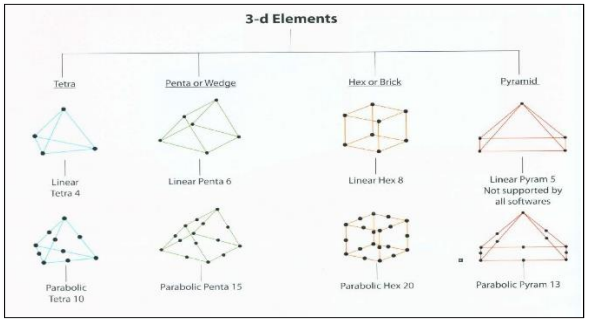


**Fig 17 Typesof3Delements**

Dimensions of the model i.e. length, breadth and height are compatible also the stressesare induced in all the 3 directions. Hence 3D solid meshing is done and parabolic tetraelements are used. Firstly 2D meshing is performed on the surface and then they areconvertedinto3Dtetraelements.

**Table1.MeshSizeSelection.**

| MESH SIZE | STRESS (N/mm2) | DISPLACEMENT (mm) | NUMBER OF ELEMENT | NUMBER OF MODES |
|---|---|---|---|---|
| 0.4 | 40.61 | 0.033 | 1532201 | 1943310 |
| 1 | 39.95 | 0.032 | 308742 | 386459 |
| 2 | 39.09 | 0.030 | 63121 | 77899 |
| 3 | 37.72 | 0.028 | 23583 | 28665 |
| 4 | 35.19 | 0.025 | 11849 | 14183 |

Mesh size is selected with the help of Convergence criteria. Iterations were conductedwith different mesh sizes. The values of stresses, displacement and time taken for solvingwith different mesh sizes has been tabulated and the optimum mesh size of 2 mm isselected having less deflection in stress & deformation values than other values alongwithlessersolvingtime.

Once the component is meshed, then mesh quality check is carried out. Different qualitycriteria like Aspect ratio, Warpage, Skew, Jacobian and Chord deviation are checked.Their values are compared with the standard values given in HyperMesh Guide. The failed elements are re-meshed and mesh cleanup is carried out. This is done in order to avoid heimpropermesh quality which in turn should not alter the stress and displacement results.

**Software Results:**

After solving the problem next step is known as Post Processing. In post processingtheresultsare showninuserunderstandableformat i.e. Stressimposedontheobject is shown in the form of color bands which shows how uniformly the stress isdistributed and at which point the magnitude of stress or deformation is maximum which shows where the possible failure can occur.

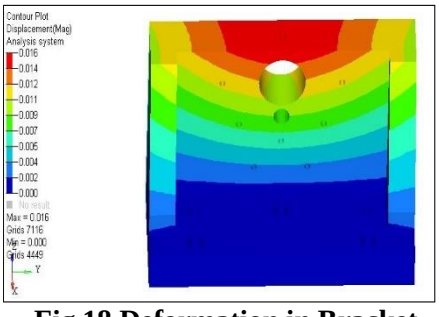


**Fig 18 Deformation in Bracket**

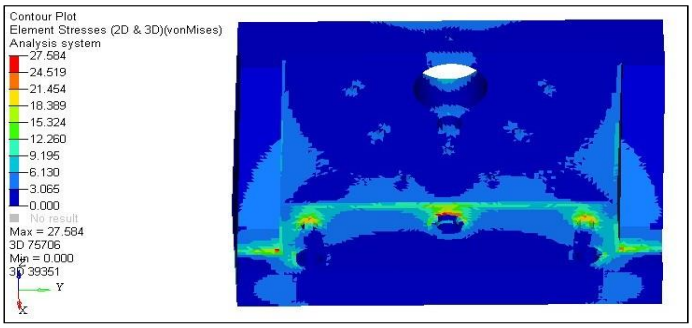


**Fig 19 StressesinBracket.**

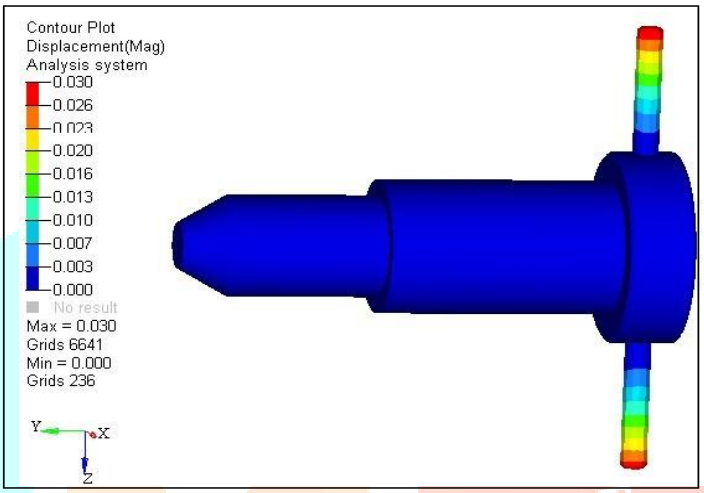


**Fig 20 Displacement in CenterPin**

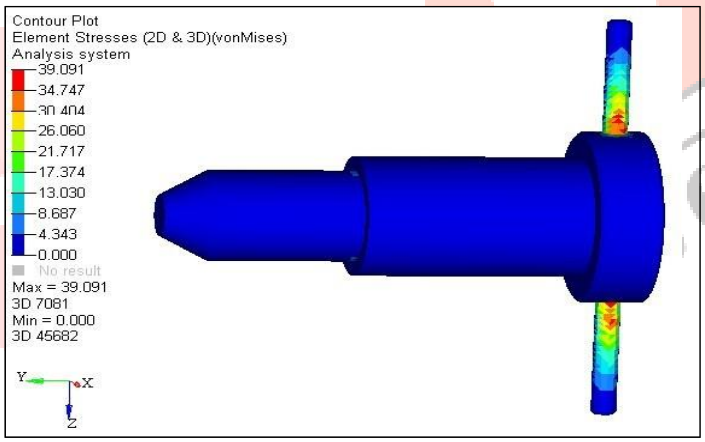


**Fig 21 Stress in Center Pin**

## III.Conclusion of Design Analysis:

After analyzing the critical components on ourmodel, we cameto know that the values of stresses induced are less than the ultimate strength of the material and also the values of deformation are in the range of few microns which indicates that it will not affect theaccuracy inthe Drilling operation and can fulfill the purpose of precisely drilling the holes in the pinion. Simulation of impact of load and its consequences is seen using theHyperMesh13.0.The obtained results were in limit according to safety and failure aspects. Therefore, it can be said that the design is safe and fool proof.

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