

Computer Aided Fixture Design for Machining of Key-ways on Eccentric Shaft

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ABSTRACT

Eccentric shaft play an important role in application of ginning machine. Machining of keyways on eccentric shaft is a important task. Machining on simple shaft is easy as compare to eccentric shaft by conventional process. machining of keyways on eccentric shaft is a time consuming process, so reducing this time is a main aim.

The job having a cylindrical shape and number of keyways are required on it at an different position. This is a challenging task for design engineer and hence Computer Aided Fixture Design (CAFD) is incorporated in manufacturing industry. It deals with the integration of CAD and CNC programming in CAM systems using software's for fixture design. Except V block, no other option is available to hold cylindrical object and hence special type of fixture is designed for this case, which can be used for machining of keyway on eccentric shaft. Fixtures reduce operation time and increases productivity and high quality of operation is possible.

Keywords- Eccentricity, Fixture design, Computer aided fixture design (CAFD)

1. INTRODUCTION

The fixture is a special tool for holding a work piece in proper position during machining operation. It is provided with device for supporting and clamping the work piece. Fixture eliminates frequent checking, positioning, individual marking, vacillate uniform quality in manufacture. This increase productivity and reduce operation time. Fixture is widely used in the industry practical production because of feature and advantages.

Eccentric shaft is a circular or cam type disc solidly fixed to rotating axel with its centre offset from that of the axel. Eccentric shaft is the important element, which plays the important role in ginning operation.

Shaft provides an oscillatory motion to moving knives and widely appreciated for its features like effective performance, corrosion resistance, reliability, long service. Reducing manufacturing cycle time and achieving high quality of operation fixture design is very important. Designer design a compact type fixture for eccentric shaft for fulfilling production target and high quality of work and increases productivity.

A key concern to a manufacturing company is the ability to manufacture high quality products in as short a time as possible. Quick release of a product into the market place, ahead of any competitors, is crucial to securing a higher percentage of the market place. Fixtures play an important role within many manufacturing processes. They accurately locate and secure a work piece during machining such that the part can be manufactured to design specifications. Thus fixtures have a direct effect upon machining quality, productivity, and the cost of products.

2. LITERATURE REVIEW

2.1 Fixture designers support expert system and concurrent engineering

Researcher give the main lines of their process, that fixture design support system is developed on the basis of an expert system shell. Researcher show how the use of that kind of tool is determinant factor for reactivity in the fixture design process in concurrent engineering.

The paper focuses of the development of fixture designer's support. Researcher present a structuring of the design method and expression of the trade rules in the expert system formalism. Researcher has developed using industrial expertise SEACMU (System Expert d'Aide il la Conception des Montages d'Usinage for expert system for fixture design). That is a fixture designers' support expert system..SEACMU is based on a fitted part modeling to the fixture design.

The correspondent model is defined from the part CAD/CAM data using RI rules. RI rules are the necessary link between the part CAD/CAM and the future design

expert system. The general organization set out on figure 3 results of the decomposition in rules basis.

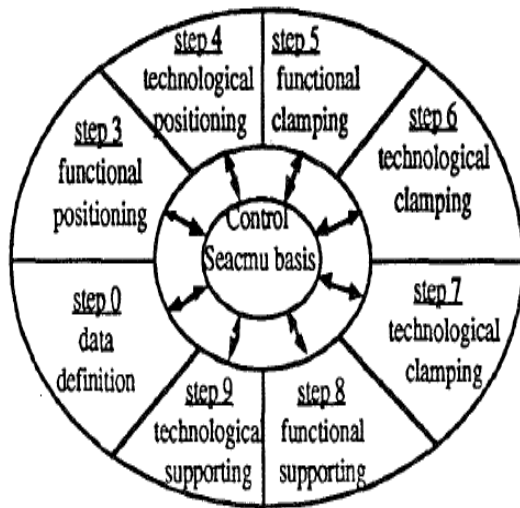


Fig.1. Knowledge bases organization[1]

A simultaneously development of the fixture design, the manufacturing schedule establishment and the NC programmed design is then allowed[1].

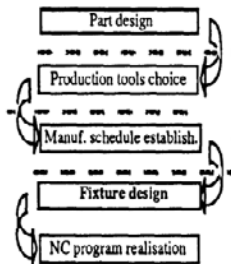


Fig.2. Sequential form of the steps [1]

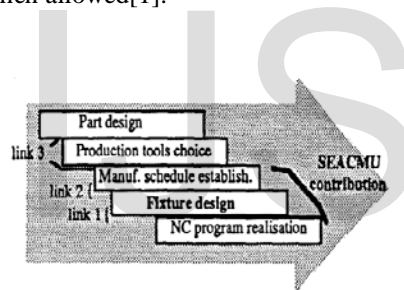


Fig.3 Concurrent engineering of the part its machining process[1]

2.2 FIXTURE DESIGN SYSTEM (COMPUTER AIDED FIXTURE DESIGN)

The manual design of fixture is traditionally a time consuming work in manufacturing and the experience of designer plays an important role in fixture design.

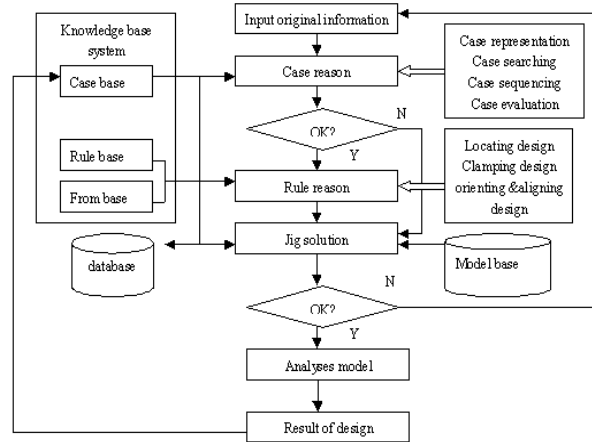


Fig.4. Flow diagram of the CAFD system [2]

The jig and fixture parts and component are divided into following categories: (a) Locating components, (b) Clamping mechanisms, (c) Tool guiding components, (d) Support components, (e) Body of fixture, (f) Fixing components for fixture, (g) Auxiliary mechanisms, (h) Operating elements, (i) Power mechanisms, (j) Miscellaneous components.. Paper explored the technology of intelligence and optimization in the process of the jig and fixture design [2].

Two conformability metrics are introduced to account for global and local conformability's his design variables are: the number and position of fixture element, fixture element length, static coefficient, fixture element tip radius, and direction of the fixture principal stiffness. Both force controlled and displacement controlled fixtures are considered.

It was found that conformability and stability can either increases nor decrease with the position of contacts depending on their proximity to the line of action of the external perturbation. Clamping intensity and principal stiffness directions have opposing effects on the stability of force controlled and displacement controlled fixtures [3].

2.3 PARAMETRIC STUDY

A. Number and position of fixture element

Fig. 4 shows that the local conformability metric for P -controlled and U -controlled fixtures (CZ , and Cza , respectively) follow very similar trends as $L4$ moves in the $+XA$ direction. In scenario #2 ($P2$), the addition of $L4$ came's an increase in both conformability metrics and also an increase in stability with respect to the reference case.

Locator $L4$ helps to support the bottom part of the sphere. This explains the increase in stability from $P1$ to $P2$. Conformability and stability decrease as $L4$ moves from $P2$ to $P5$ as shown in Fig.4

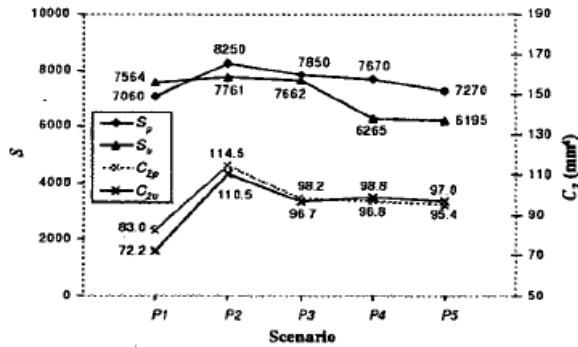


Fig.5. Effect of the number and position of fixture element[3]

B. Clamping intensity

For the case of the P-controlled fixture, the clamping Force was changed from 800 N in P1 to 900 N in P2 and to 1000 N in P3. Similarly, the prescribed clamping Displacements for P2, P3 and P4 are 12.5, 15.0 and 17.5 pm, respectively. Fig. 5 shows that S_p and C_{zp} increase With clamping intensity. Higher clamping loads produce larger work piece and contact elastic deformations causing an increase in C_{zp} . In the case of the U-controlled fixture stability decreases slightly with increasing clamping intensity while C_z is not significantly affected.

The normal clamping loads necessary to produce the prescribed displacements of the U-controlled fixture do not change significantly when going from 12.5 to 17.5 pm ($D'F_{12.5} = 659$ N, $D2F_{12.5} = 590$ N for 12.5 pm; $DIF_{17.5} = 680$ N, $D2F_{17.5} = 623$ N for 17.5 pm). As a result, the fixture-work piece reaction forces remain almost unchanged from P1 to P4. This explains the small variation of C_{zu} shown in Fig.5 [3].

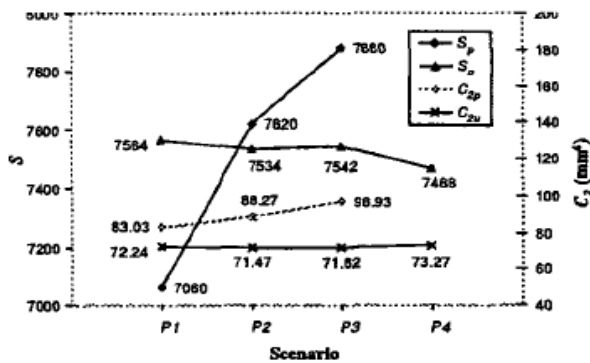


Fig.6. Effect of the Clamping Intensity [3]

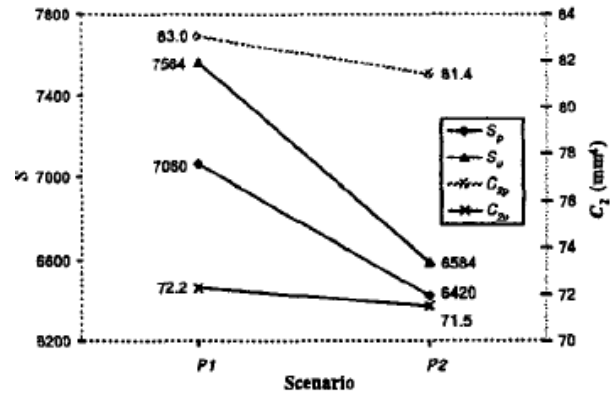


Fig.7. Effect of the Clamp Orientation.[3]

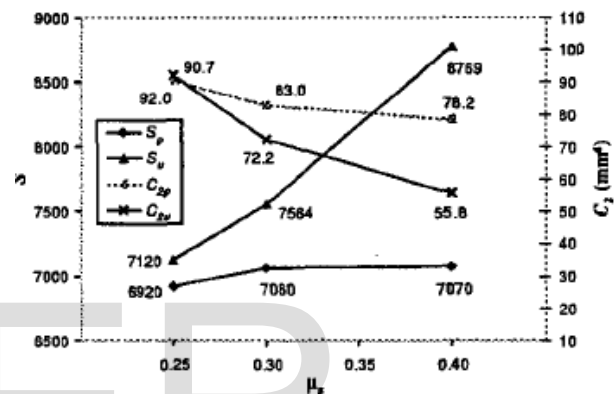


Fig.8. Effect of the Static Coefficient of Friction [3]

Requirements should be satisfied for fixture:(i)total restraint of the work piece or form closure;(ii)accurate locating of work piece ; (iii)limited deformation of work piece; no interference between fixture components and machine tool;(iv)including ease of loading/unloading a work piece. The first two requirements that are essential for the design of fixture layout and can be viewed as the first step of fixturing system design for determination of the number, type and location of fixturing points. researcher propose an efficient algorithm to identify seven frictionless fixturing point ensuring form closure and small positioning error of the work piece from original dense set. Paper addressed the problem of fixture layout design for a 3D curved work piece [4].

Facing a continuously increasing competition worldwide, manufacturing industry are undergoing a critical transition from traditional methods to advanced manufacturing technology many of which are computer based.

In order to increase competitiveness, manufacturers are seeking to improve product quality. Lower production costs, and increase the speed of bringing innovative products to the market. Early years of computer aided fixture design (CAFD), the designer simply used the CAD tool to assemble the drawings on computer screen with a library of standard fixture components.

Fixture assembly operations are performed by specifying coordinates and rotation angles in x-y plane, which still takes time for manipulating geometric entities. One of the most important goals of CAFD is to reduce the manufacturing lead time. the problems associated with current CAFD applications include: 1) functions of automated fixture design systems are limited and many complex fixture designs still need human interaction and using CAFD systems with commercial CAD packages is time consuming as it manipulates geometric entities around on screen.

Outline of rapid fixture design system (RFDS) which includes several modules and databases: a) locating method selection's) work piece information retrieval; c) locator/clamp selection; d) fixture unit generation and placement; e) interactive fixture design modification; f) locating method database and g) fixture component database. In fixture design, the locating method and locator clamp selection are based on fixturing requirement analysis. To help fixture designers in the locating method selection, a menu-driven locating method classification tree is designed which makes the fixture design process more logical and requires less experience.

Researcher presents a rapid fixture design system which combines the automated modular fixture configuration design technique for fixture unit generation and interactive fixture design functions for selections of locating methods and locating clamping components [5].

Only concerned with achieving three point contacts, which is necessary to re-use the fixture, Manufacturing and installation of fixtures are costly for high volume production runs. In this paper we address the problem of the re-usability of fixtures.

Researcher addresses both types of variation in the context of modular fixtures. For tolerance variation, they give a method for comparing fixtures in terms of how much geometric tolerance they will permit before failing. For design variation, they identify design rules that can rapidly check if a proposed part design is consistent with a given previous fixture [6].

Fixture design is a critical manufacturing activity in the production cycle and has great effect on product quality, lead time, and cost targets.

With the development of computer aided fixture design (CAFD) system, the efficiency of fixture design and the cost of production have been improved obviously. Fixture planning is an important early step in CAFD process, which determines the locating and clamping points on work piece surfaces, it contributes so much to fixture design.

Fixture requires simple configuration, small clamping force, multi-varieties and small batch production, short design and manufacturing cycle, and low cost. Compare to conventional manufacturing processes, the primary advantage of RP is its ability to create almost any shape or geometric feature, in this case, production efficiency and manufacturing flexibility will be greatly improved.

The evaluation method proposed in this paper is going to evaluate the clamping plan from several aspects as follows: Area factor. Stability factor, location of clamping point factor. The automation of fixture planning plays a vital role in improving the efficiency of fixture design and manufacture [7].

Fixture layout is the primary task of the fixture design. Fixture design is a practical problem and is crucial to product manufacturing. During the course of manufacturing processes, such as machining, assembly, or inspection, it is necessary to immobilize, support, and locate the work piece, this is also referred to as work holding.

A fixture is comprised of a number of basic work holding elements such as locators, supports, and clamps. The task of fixture layout is to determine the number, type, and location of the work holding elements. Second task is referred to as fixture setup, and its main concern is to avoid collision and interference between the machine tool and the fixture. Basic Fixture Components is locator, support, clamps. Fixtures have six basic functional Requirements: (a) stable resting, (b) accurate localization.(c) Support reinforcement, (d) stable clamping, (e) force-closure (or total restraint), and (f) quality performance.

The focus of the researcher paper is on effective fixture modeling and efficient numerical techniques for automatically generating, analyzing, and optimizing fixture layout designs for any complex-shaped 3D work pieces [8].

3. MATERIAL OF FIXTURE

Steel specified by SAE (Society of Automobile Engineers) and AISI(American Iron and Steel Institute) classification and standards.eg. SAE 1020 first two digit indicate the class to which the steel belongs, the last two digit indicate carbon contain.

CLASS	TYPES OF STEEL
1) 10XX	Plain carbon steel
2) 11XX	Free cutting (carbon)steel
3) 13XX	Manganese steels
4) 2XXX	Nickel steels
5) 3XXX	Nickel –chromium steels
6) 4XXX	Molybdenum steels
7) 5XXX	Chromium steels
8) 6XXX	Chromium vanadium steels
9) 7XXX	Tungsten steels
10) 8XXX	Nickel chromium molybdenum steels
11) 9XXX	Silicon manganese steels

SAE 1015 and below are highly ductile and are used for press work but not for fixture.(ref from Jig and Fixture Design manual by Erik Karl Henriksen)

4 . CHALLENGES OF MACHINING OF KEY-WAYS ON ECCENTRIC SHAFT BY CONVENTIONAL METHOD

With the advent of CNC machining technology and the capability of multi-axis machines to perform several

operations and reduce the number of set-ups, the fixture design task has been somewhat simplified in terms of the number of fixtures which would need to be designed. However, there is a need to address the faster response and shorter lead-time required in designing and constructing new fixtures.

Problems occurring in today's scenario for machining on eccentric shaft by conventional method (cylindrical objects) are:-

- Machining of key ways inline. on eccentric shaft
- Unavailability of fixture for machining of keyways on eccentric shaft.
- Poor repeatability and accuracy.

in today's scenario there are very few fixtures are available for machining on eccentric shaft.

As application for machining of keyways by the use of fixture differs from industry to industry because dimensions required by industries differ from each other. Main requirement of customer is keyways produced on eccentric shaft should have high degree of accuracy and it is used for mass production. Also it can withstand stresses acting on it during operation and can run for long life.

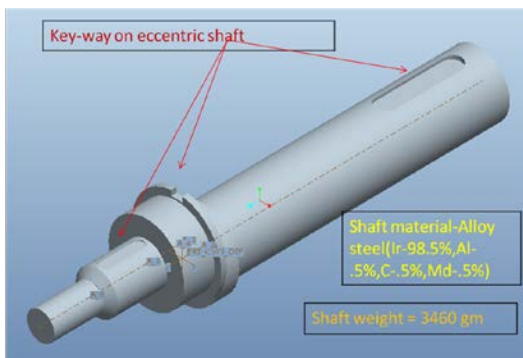
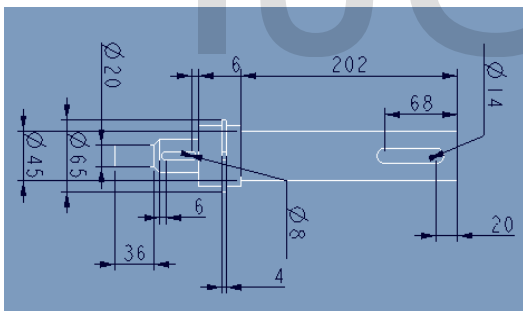


Fig 9. Machining of keyways on eccentric shaft

4. DEVELOPMENT OF FIXTURE ASSEMBLY FOR MACHINING OF KEY WAYS

The steps involved for development of fixture for machining of keyways on eccentric shaft are as follows:

- Analytical design for fixture.
- 3 - D Modeling in PRO – ENGINEER Wildfire 5.0
- Fixture assembly
- Analysis by using ANSYS.

4.1. Analytical design for fixture:-

It is included that design of base plate, base v-block, threaded block, supporting v-block, clamp, hexagonal bolt with washer, supporting pin.

4.2. 3 D Modeling in PRO – ENGINEER Wildfire 5.0:-

It is included that generating of 3D model of all details part Of fixture like base plate, base v-block, threaded block, supporting v-block, clamp, hexagonal bolt with washer, supporting pin.

4.3. Fixture assembly:-

It is included that assemble of all the details part of fixture step by step is carried out.

4.4. Analysis by using ANSYS:-

It is included that static analysis is carried out, deflection and von mises stresses find by the use of software.

Approach to fixture design:

- Analysis of the work piece drawing.
- Identification of candidate elements (machined surfaces for locating, possible clamps positions, important regions of work piece, tool path, possible tool interference points, etc.).
- Support, location, clamping, base, guiding, fasteners taken in consideration.
- Methodology (modular, vice, v-block, point surface, angular structure, multiworkpiece clamping, 3-2-1 principle etc.).
- Identification of solutions (successful sequence of local solutions and creation of a consistent solution, selection of a pattern for modular fixtures (positioning of 2 or more work pieces)
- Fixture design
- Building of assembly.

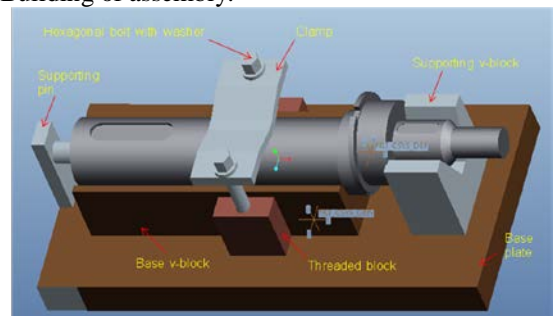


Fig 10. Suggested fixture assembly for machining of keyways on eccentric shaft

5. DESIGN OF VARIOUS FIXTURE PARTS

5.1.Design of base plate:-

The base plate is design by considering the specifications of a machine. as the fixture is mounted on table and hence the dimension of a table is key factor, while designing the base plate, the length, width and height of base plate is taken as

Consider base plate length(l)=300mm

Consider base plate width(b)=150mm

Consider base plate height(h)=24mm

5.2.Design of base v-block:-

The base v-block is design by considering the specifications of a machine. as the fixture is mounted on table and hence the dimension of a table is key factor while designing the base v-block, the length, width and height of base v-block is taken as 250,66,45 respectively.

Consider base v-block length(l)=250mm

Consider base v-block width(b)=66mm

Consider base v-block height(h)=45mm

5.3.Design of threaded block:-

The threaded block is used to support the clamping element. The dimension of threaded block depend on the support that has to given to clamping element. The length, width, and height of thread block can be taken

as 46,26,45respectively.

Consider threaded block length(l)=46mm

Consider threaded block width(b)=26mm

Consider threaded block height(h)=45mm

5.4.Design of supporting v- block:-

The supporting v-block provide the extra support to eccentric shaft and its dimension depends on

Consider supporting v- block length(l)=46mm

Consider supporting v- block width(b)=66mm

Consider supporting v- block height(h)=46mm

5.5.Design of Clamp :-

A clamp is a force-actuating mechanism of a fixture. The forces exerted by the clamps hold a part securely in the fixture against all other external forces.

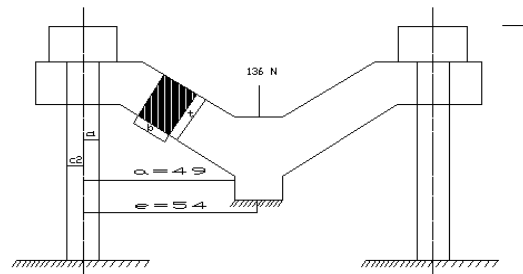


Fig11.Clamp of Fixture

a-distance from bolt central axis to clamp supporting one end.

e-distance from bolt central axis to clamp supporting central axis.

b-width of square c/s of clamp.

x- length of square c/s of clamp.

C1,C2 –radios of clamp hole

a=49,C1=5,C2=5

design of width of clamp(b):-

$$b= C1+C2 \quad (1)$$

b=10mm

design of polar moment of inertia(J):-

$$J = \pi/64 \times d^4 \quad (2)$$

J = 219.78 x 10³ mm

Design of Torque of clamp:-

Calculating power(P):-

$$P = 2\pi NT/60 \quad (3)$$

P=3.75W

$\therefore Z=1/6 \times tb^2$ **(10)**

Design of resisting torque(Tr):-

Z= 16.66 t

$T=P \times 60 / 2 \pi N$ **(4)**

($\therefore F_b=52.5$)

Tr=24.86 N-mm

t=8.39mm(for bending)

Calculating Maximum torque(τ_{max}):-

As per calculation ,We observed that thickness of clamp is calculated for tensile,shearing,bending i.e

$\tau_{max} = Kts \times Tr$ **(5)**

$\tau_{max}= 43.505 \times 10^3$ N-mm

t=4.096mm –tensile \approx **t=5mm**

t=6.82mm---tensile \approx **t=7mm,**

t=8.39mm---bending \approx **t=9mm,**

calculating tensile stress:-

The material of eccentric shaft is alloy steel i.e SAE1040,The shaft is transmitting 5Hp at 1440 rpm.The yield tensile stress(δ_{yt}), ultimate tensile stress(δ_{ut}), yield shear stress(δ_{ys}), modulus of elasticity(E), modulus of rigidity(G), are350mpa,632mpa,210mpa,203mpa,78mpa

take dimension of thickness as per your design i.e **t=7mm** because it get the maximum tensile stress on shaft and block.

Let, F.s-factor of safety, P-load on clamp,A-area of clamp

$\sigma = \delta_{yt} / F_s$ **(6)**

$\sigma = 87.5$ N/mm²

calculating bending stress:-

6. RESULTS & DISCUSSION

Steps of Analysis

- Import model in IGES format in Ansys-12
- Divide the model in elements by meshing
- Apply the force
- Solve for stress calculation

$\tau_b = \delta_{ys} / F_s = 210 / 4 = 52.5$ N/mm² **(7)**

$\tau_b = 52.5$ N/mm²

Combine Bending and Tensile:-

The force acting on fixture is 140N and hence this much force is applied fixture and deformation and von-misses.

$I = tb^3 / 12$

$I = 83.33t$

$\sigma = P/A + P.a.c/I, (A=bt=10t)$ **(8)**

t=4.096mm -----(for tensile)

$52.5 = 358.46/t$ **(9)**

t=6.82mm -----(for tensile)

$F_b = Mb/Z = p \times e / Z = (136 \times 54) / Z$

Fb-bending force.

Mb-bending moment

$F_b = (136 \times 54) / Z$

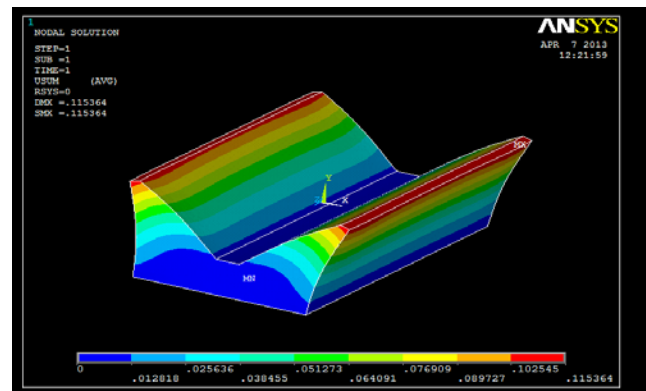


Fig 12.shows static structural Deformation of v-block.

-It is found that deflection of base of v-block with analytical calculation is.00141mm and with ANSYS is 0.115364mm.

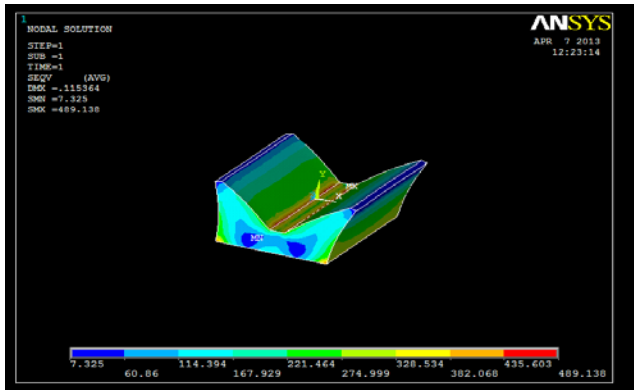


Fig 13. Shows stress Analysis of base block by ANSYS

-It is found that von-misses stress acting on base v-block with analytical calculation is 515.26Mpa and ANSYS calculated value is 486.138Mpa.

fig.14 shows deformed shape of base v-block.

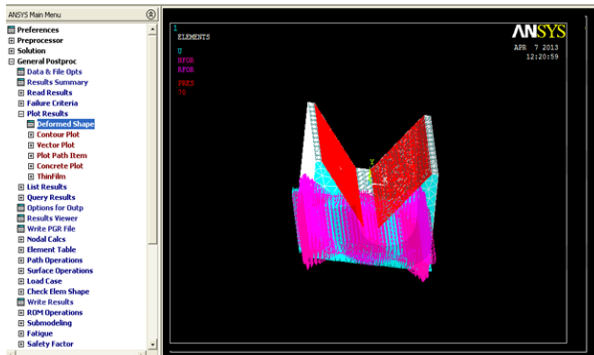


Fig.14. Deformed shape of base v-block

fig. 15. shows minimum and maximum deformation of base v-block.

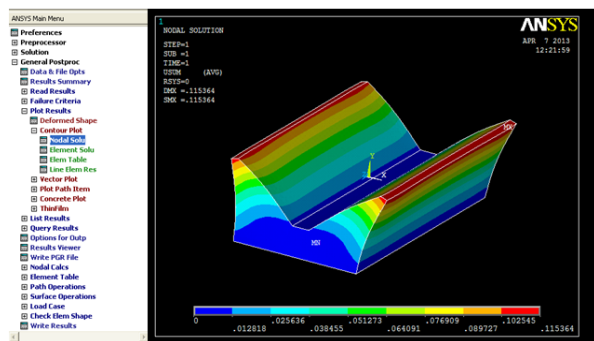


Fig. 15 Minimum and maximum deformation

-Following fig. show minimum and maximum Von misses stress or (equivalent tensile stress) of base v-block .

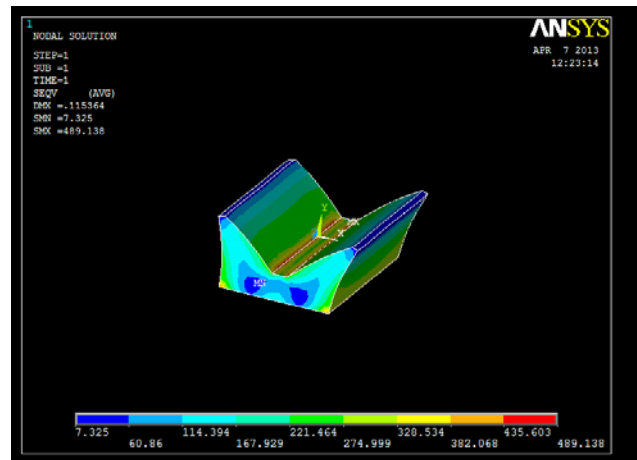


Fig.16. Minimum and maximum von misses stress or (equivalent tensile stresses)

7. CONCLUSION

The standard value of allowable deflection in alloy steel is 4.389 mm, and von misses stress is 620.442mpa. The deflection with analytical calculation is 0.0014mm and with ANSYS is 0.115364 mm , which is comparatively less than allowable standard values so design is safe, The von misses stress with analytical calculation is 515.26mpa and with ANSYS is 489.138mpa, which is less than std values. So it can be said that design is safe.

TABLE : Comparison between analytical calculation and ANSYS Results

Parameter	Finite element Method Results	ANSYS Results	Remark
Deflection in mm	0.00141 mm	0.115364 maximum	Safe
Von misses stress in MPa	515.26 Mpa	489.138 maximum	Safe

- The industry person or user will satisfy with the use of this fixture.
- The user able to provide best product to customer on time.

- The user will provide high degree of accuracy in machining of keyways.
- The user get best possible fixture for eccentric shaft.
- The cost of material handling and scrap is reduced.

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