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EXPERIMENTALINVESTIGATION AND OPTIMIZATION OF MACHINING FIXTURE LAYOUT BY SIMULATED ANNEALING ALGORITHM

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ABSTRACT : *Fixture is a precision device for restraining the work piece during manufacturing, inspection, assembly and transportation. Fixtures are used in many manufacturing processes to hold work piece and to reduce the set up time. The position of fixture elements is called as fixture layout. Placing the clamps and locators in wrong positions may disturb the equilibrium of the work piece, resulting in excessive deformation of the work piece. Hence optimization of fixture layout to minimize the work piece deformation is one of the critical aspects in the fixture design process. In this paper discussed about to find the optimum location of the clamps.*
Key words*: Fixture Layout, Optimization*

I. INTRODUCTION

Machining fixture is a precision device meant for locating and constraining the work piece during machining. A machining fixture is used to establish and maintain the required position and orientation of a work piece so that cutting operations can be performed on the work piece. It is a critical link in the machining system as it directly affects operational safety and part quality. A typical machining fixture consists of a base plate and a number of locators and clamps. Locators are passive fixture elements used to position the work piece while clamps are active fixture elements that can be actuated mechanically, pneumatically, or hydraulically to apply clamping forces onto the work piece so that it can resist external forces generated by the machining operation. There are a variety of fixture designs. The geometry of the contact region between a fixture element and work piece can be a point, line, or plane. An important consideration in the fixture design process is to design the fixture layout and optimization of clamping forces required. The elastic deformation of the work piece can be minimized by designing the optimum fixture layout and clamping forces. Proper fixture design is crucial to product quality in terms of precision, accuracy and surface finish of the machined parts.

II. FIXTURE

Fixtures is a rigid mechanical device which enables easy, quick and consistently accurate locating, supporting and clamping, blanks against cutting tool(s) and results faster and accurate machining with consistent quality, functional ability and interchange ability. There are many standard work holding devices such as jaw chucks, machine vises, drill chucks, collets, etc. which are widely used in workshops and are usually kept in stock for general applications

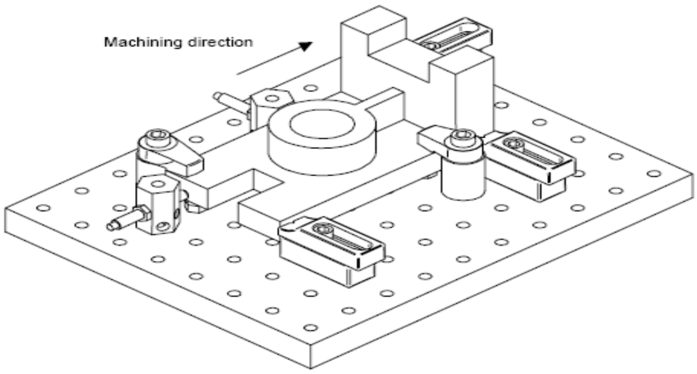


Figure 1A typical fixture, shown with a work piece

2.1. Fixture Layout

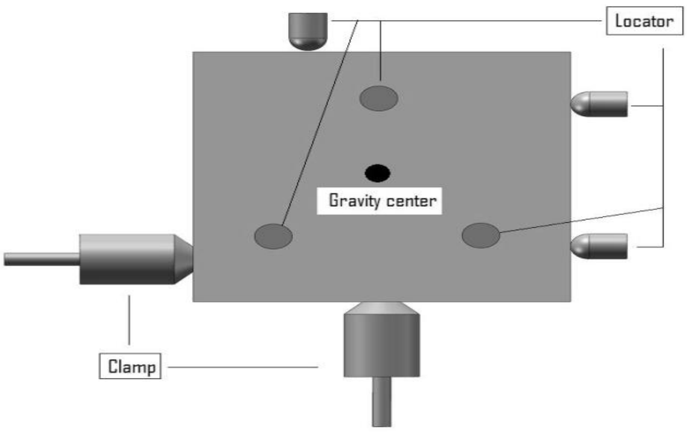


Figure 2 Fixture Layout for 3-2-1 Locating Method

III. ASSUMPTIONS OF THE PROJECT

Fixture layout optimization is a vast area for research work. So the project scope is restricted to the following points.

a) The project work is assumed to be performed for reducing the dimensional / form accuracy of fixture layout.
b) In the fixture optimization problem, we need to minimize the maximum deformation in the work piece. The parameters which influence the deformation of the work piece are
   I. Clamping forces
   II. Machining forces
   III. Position of locators and clamps
   IV. Material of the work piece
   V. Number of locators and clamps
c) The machining forces that are required to carry out the end milling operation are selected for analysis.
d) The work geometry is assumed to be two-dimensional (2D) rectangular shape with no hollow area in it.
e) Fixture layout scheme used is 3-2-1, specifically three locators and 2 clamps. This method provides the maximum rigidity with the minimum number of fixture elements.
f) Only the planar forces are assumed to be acting on the work piece. The forces acting normal to the plane is out of focus.

IV. METHODOLOGY

The fixture layout optimization problem is considered as: finding the positions of the locators and clamps, in such a way that work piece deformation at specific region is minimized. In machining process, fixtures are used to keep work pieces in a desirable position for operations. The most important criteria for fixture layout are work piece position accuracy and work piece deformation. A good fixture design minimizes work piece geometric and machining accuracy errors. Another fixture layout requirement is that the fixture must limit deformation of the work piece. It is important to consider the cutting forces as well as the clamping forces. In the fixture layout optimization problem, the objective is to find out the positions of locators and clamps that minimize the deformation occurring during machining of the work piece.

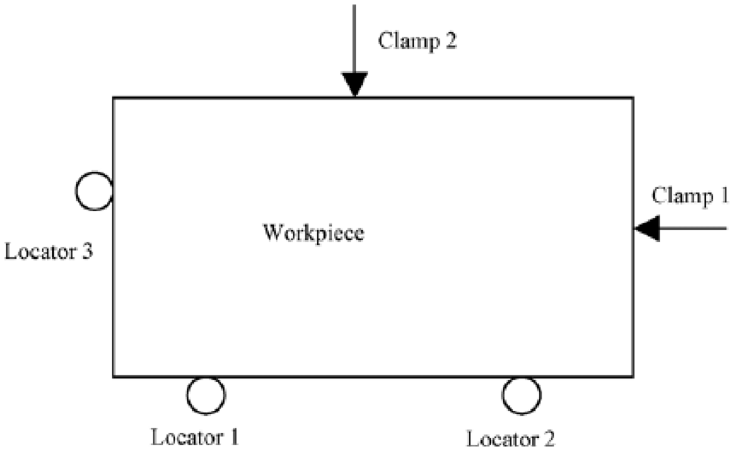


Figure 3 Fixture Layout Scheme, 3-2-1, for 2D work piece

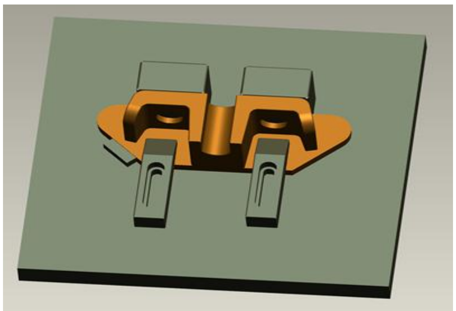
The work piece (Figure 3) is constrained by three locators and two clamps. This forms a fixture layout. If the position of any one of the locators or clamps is changed, then the changed positions of locators and clamps form another fixture layout. Thus there are infinite possible fixture layouts from which the best suitable fixture layout is selected that have minimum deformation values.

4.1. Mathematical Model

The fixture layout optimization problem is defined as finding the positions of the locators and clamps, so that work piece deformation at specific region is minimized. Note that number of locators and clamps are not design parameter, since adopt the 3-2-1 locating scheme. In this scheme, three locators and two clamps are used to rigidly support one work piece. Hence, the design parameters are selected as locator and clamp positions. Friction is not considered in this paper.

Consider a 2D fixture layout parameters and tool path are shown in Figure 4

Figure 4Proposed fixture layouts



In the figure5 above, the terms L_1, L_2, L_3 are the positions of locators, L_4 and L_5 are the positions of clamps. F_{c1} and F_{c2} are the clamping forces acting on the work piece surface.

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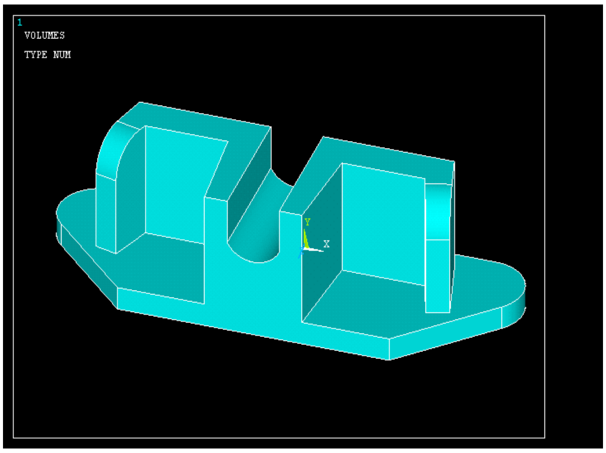


Figure 5.Component

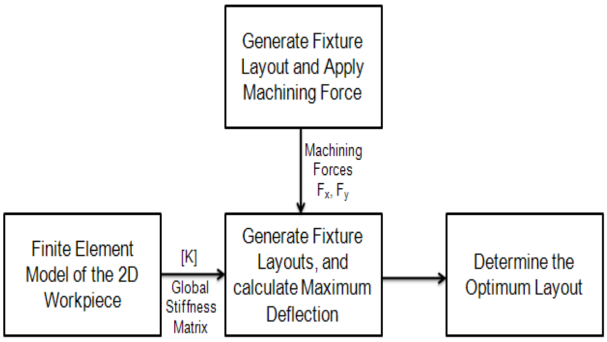
Locator / clamp	X	Y	Z
Locator 1	-60 < X < -97.2721	0 < Y < 10	30.7279 < Z < 68
Locator 2	19.5 < X < 46,1549	17.5 < Y < 52.5	10
Locator 3	-19.5 < X < -46.1549	17.5 < Y < 52.5	10
Clamping 1	-30 < X < -60	10	38 < Z < 68
Clamping 2	30 < X < 60	10	38 < Z < 68

Table 1 Locators and Clamp Region

4.2. Finite Element Method

Finite element method is a numerical method for solving engineering problems. In this method, a continuum in which the analysis to be carried out is subdivided into smaller elements, called finite elements (figure 7). The element equation is derived for each element. Then the body is considered as the assemblage of these elements connected at finite number of joints called nodes. In other words, we formulate the equations for each finite element and assemble them to obtain the solution of the whole body.

When we use finite element method (FEM) for fixture layout optimization problem, the computer discreteness the work piece into finite number elements. The stiffness matrix is calculated for each element, and the global stiffness matrix is calculated by properly assembling the element stiffness matrix values. Then the force vector is generated to find out the displacement values in each node. The displacement values are then compared for all possible fixture layouts. The fixture layout that causes the minimum deformation is then selected as optimum fixture layout. Finite Element Method (figure 6) reads this file and computes fitness value for current locator and clamp positions.The block diagram shown in Fig. 6 illustrates the overall process.



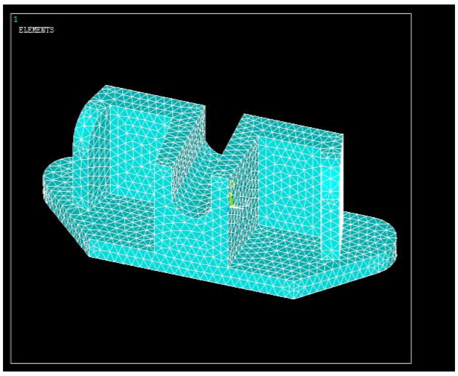


Figure 6. Block Diagram of fixture process using FEM.

Figure 7 Component- mesh the layout model

In the implementation, finite element analysis software is built for the fixture layout optimization of the work piece. This software was chosen since it can output the global stiffness matrix for a general work piece mesh. The global stiffness matrix is extracted from the finite element software and the layout/clamping force algorithm starts with the stiffness matrix as input. The layout and clamping force optimization algorithms have been developed to handle any 2-D geometry that has been meshed using elements with three degrees of freedom at each node.

The user inputs the candidate locating and clamping regions by specifying the work piece nodes that are bounded by them. The machining error, i.e., work piece form error, can be directly related to the work piece elastic deformation at the machining point. Assuming that the number of fixture elements and the potential regions on the work piece surface where they need to be applied are known, optimal fixture design involves determining the fixture layout and clamping forces that minimize the deformation of the machined surface over the entire cutting operation.

The locators and clamps are positioned in the work piece so as to constrain the movement of work piece. In the project work, the locators are used to restrict the movement in the normal direction to the edge in which the locator is placed. Clamps are used not only to support the work piece, but also to clamp it rigidly by applying the force. The value of clamping force and the corresponding planar forces are listed in the below:

Planner force FxandFy889.6, Clamping force 1788 Values are Newton.

Cutting forces are applied sequentially to each machining surface node and the deformation for each load application is computed. The deformation for the entire process is then determined from the maximums for each load application. The finite element Method is used to minimize the deformation for the generation by varying the positions of the locators and clamps.

4.3. Calculating Deformation Values

Finite element method calculates the deformation values solving the elemental nodal equations and global equations. For instance, consider the rectangular work piece shown in the figure below. The work piece is discredited into two finite triangular elements (figure 8). The numbering of nodes and elements are mentioned for the two elements.

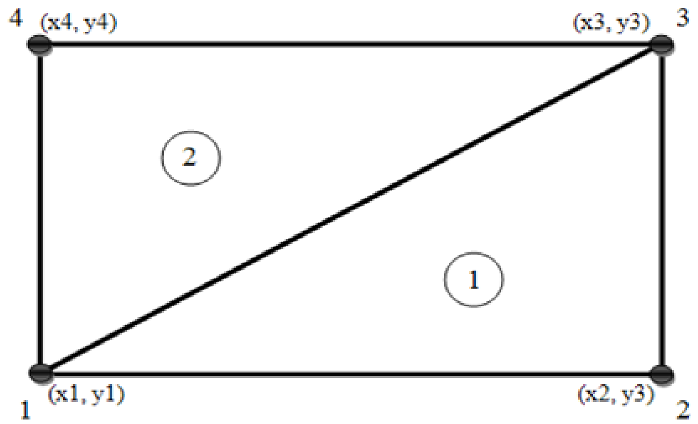


Figure 8. Planar work piece divided into Triangular Elements

Elemental Stiffness matrix, $[K_1]$, for a triangular element 1, is given by the following equation:

$[K_1] = [B]^T [D] [B] A t$ -- (6.1)

Where,

An→ Area of the triangular element.

$$A = \frac{1}{2}\begin{vmatrix} 1 & x1 & y1 \\ 1 & x2 & y2 \\ 1 & x3 & y3 \end{vmatrix}$$ --- (6.2)

t→ Thickness of the element.

[B] →Strain Displacement Matrix

$$[B] = \frac{1}{2}\begin{vmatrix} q1 & 0 & q2 & 0 & q3 & 0 \\ 0 & r1 & 0 & r2 & 0 & r3 \\ r1 & q1 & r2 & q2 & r3 & q3 \end{vmatrix}$$ ------------------------ (6.3)

Where, q1 = y2 – y3; q2 = y3 – y1; q3 = y1 – y2
r1 = x3 – x2; r2 = x1 – x3; r3 = x – x1

[D] → Stress Strain Relationship Matrix.

$$[D] = \frac{E}{(1+v)(1-2v)} \begin{bmatrix} (1-v) & v & 0 \\ v & (1-v) & 0 \\ 0 & 0 & \frac{(1-2v)}{2} \end{bmatrix} \text{-------------- } (6.4)$$

where,

E → Young's Modulus of Elasticity.

v→ Poisson's Ratio.

$$\{X\} = \begin{Bmatrix} u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_3 \\ v_3 \\ u_4 \\ v_4 \end{Bmatrix} \text{-- } (6.7)$$

where,

u_1, $u_{2,}$ u_3 and u_4 are the nodal displacements caused in x – direction.

v_1, $v_{2,}$ v_3 and v_4 are the nodal displacements caused in y – direction.

The general deflection vector equation for the triangular element is given by:

$\{X\} = [K]^{-1} \{F\}$ --- (6.8)

where,

[K]is the global stiffness matrix of the work piece

{F} is the force vector of applied forces, and

{X} is the vector of nodal displacement (elastic deformations).

The displacement values u_1, $u_{2,}$ $u_{3,}$ $u_{4,}$ v_1, $v_{2,}$ v_3 and v_4 are calculated for the rectangular work piece in the example. The displacement value is the deformation value for the work piece.e work piece.

LOCATOR / CLAMP	X	Y	Z
LOCATOR 1	-76.42	5	48.26
LOCATOR 2	32.83	35	10
LOCATOR 3	-32.83	35	10
CLAMP 1	-45	10	43
CLAMP 2	45	10	43

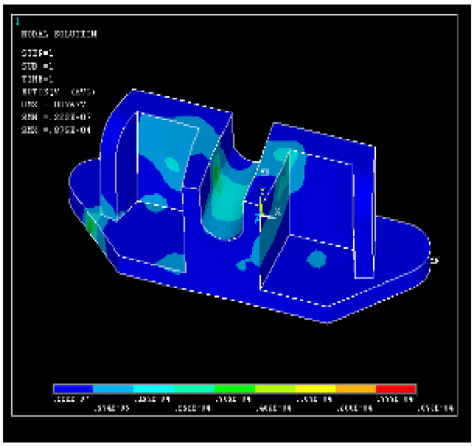
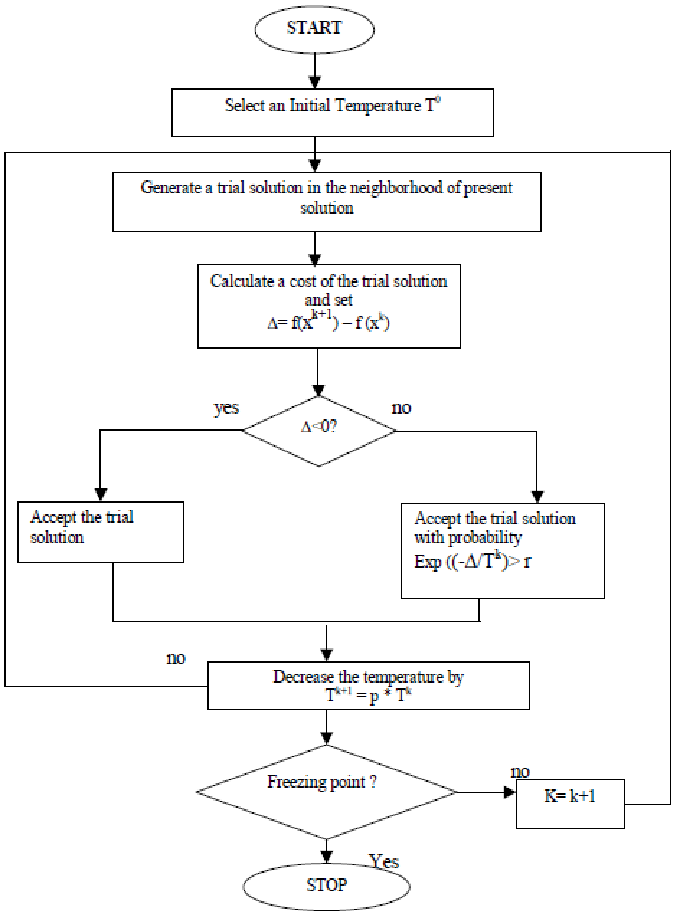


Table 2 Optimum Range of Locators Figure 9 Optimum Position and Clamps

Simulated annealing algorithm:

Simulated annealing (SA) is a random-search technique which exploits an analogy between the way in which a metal cools and freezes into a minimum energy crystalline structure (the annealing process) and the search for a minimum in a more general system; it forms the basis of an optimisation technique for combinatorial and other problems. Simulated annealing was developed in 1983 to deal with highly nonlinear problems. SA approaches the global maximisation problem similarly to using a bouncing ball that can bounce over mountains from valley to valley. It begins at a high "temperature" which enables the ball to make very high bounces, which enables it to bounce over any mountain to access any valley, given enough bounces. As the temperature declines the ball cannot bounce so high, and it can also settle to become trapped in relatively small ranges of valleys. A generating distribution generates possible valleys or states to be explored. An acceptance distribution is also defined, which depends on the difference between the function value of the present generated valley to be explored and the last saved lowest valley. The acceptance distribution decides probabilistically whether to stay in a new lower valley or to bounce out of it. All the generating and acceptance distributions depend on the temperature.

Simulated annealing is a point-by-point method. The algorithm begins with an initial point and a high temperature T. A second point is created at random in the vicinity of the initial point and the difference in the function values (Δ) at these two points is calculated. If the second point has a smaller function value, the point is accepted; otherwise the point is accepted with a probability exp $^{(-\Delta/T)}$. This completes an iteration of the simulated annealing procedure. In the next generation, another point is created at random in the neighborhood of the current point and the metropolis algorithm is used to accept or reject the point. In order to simulate the thermal equilibrium at every temperature, a number of points (n) is usually tested at a particular temperature, before reducing the temperature. The algorithm is terminated when a sufficiently small temperature is obtained or a small enough change in function values is found.



V. CONCLUSION

Dimensional accuracy and form accuracy of a work piece are influenced by the fixture layout selected for the machining operation. Hence, optimization of fixture layout is a critical aspect of machining fixture design. In this project work, The results were discussed in this paper. The results also show that the fitness value converges when number of nodes and / or the number of iterations increases. Thus, it is concluded that the fixture layout optimization using ansysgives better results and consumes less computation time.

REFERENCES

[1]. S. Vallapuzha, E.C. De Meter, S. Choudhuri and R.P. Khetan, "An investigation into the use of spatial coordinates for the genetic algorithm based solution of the fixture layout optimization problem", International Journal of Machine Tools and Manufacture 42 (2002) 265–275.

[2]. K. Krishnakumar and S.N. Melkote, "Machining fixture layout optimization", International Journal of Machine Tools and Manufacture 40 (2000) 579– 598.

[3]. Wang MY, "A full-kinematic model of fixtures for precision locating applications" in IEEE/RSJ international conference on intelligent robots and systems, Maui (HI USA); 2001. p. 1135–40.

[4]. B. Li and B.W. Shiu, "Principle and simulation of fixture configuration design for sheet metal assembly with laser welding. Part 2. Optimal configuration design with the genetic algorithm", International Journal of Advanced Manufacturing Technology 18 (2001) 276–284.

[5]. Y.G. Liao, "A genetic algorithm-based fixture locating positions and clamping schemes optimization", Proceedings of the Institute of Mechanical Engineers. Part B, Journal of Engineering Manufacture 217 (2003) 1075–1083.

[6]. A.S. Kumar, V. Subramaniam and K.C. Seow, "Conceptual design of fixtures using genetic algorithms", International Journal of Advanced Manufacturing Technology 15 (1999) 79–84.