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IJIEMR Transactions, online available on 15th Dec2015. Link :http://www.ijiemr.org/downloads.php?vol=Volume-4&issue=ISSUE-4

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Volume 04, Issue 04, Pages: 47– 56.

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# MACHINING FIXTURE LAYOUT OPTIMIZATION USING GENETIC ALGORITHM AND ARTIFICIAL NEURAL NETWORK

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**ABSTRACT**—Genetic algorithm (GA) is proven to be a useful technique in solving optimization problems in engineering. Fixture design has a large solution space and requires a search tool to find the best design. Few researchers have used the GAs for fixture design and fixture layout problems. Either separately along with FEM, GA has been used for fixture layout and clamping force optimization problems, Siva Kumar and Paulraj, Prabhakaran et. To compare and identify the most suitable machining fixture layout optimization method for the fixture layout optimization problems, GA based and GA-ANN based fixture layout optimization methods have been presented and results are compared in this chapter

## 1.INTRODUCTION

**1.1 GENETIC ALGORITHM** Genetic algorithms are widely studied, experimented and applied in many fields of engineering. GA is a stochastic search procedure for combinatorial optimization problems, based on the mechanism ofnatural selection and natural genetics. The work flow of most common types of genetic algorithms is shown in Figure 1.1. The algorithm starts with a randomly generated initial set of population called chromosomes that represent the solution of the problem. These are evaluated for the fitness function and they are selected according to their fitness value. Many selection procedures are currently in use to generate next generation. Most of the selection procedures are based on the fitness value of the individuals of current generations. These individuals then "reproduce" to create one or more offspring, after which the offspring are mutated randomly. This continues until a suitable solution has been found or a certain number of generations have passed.

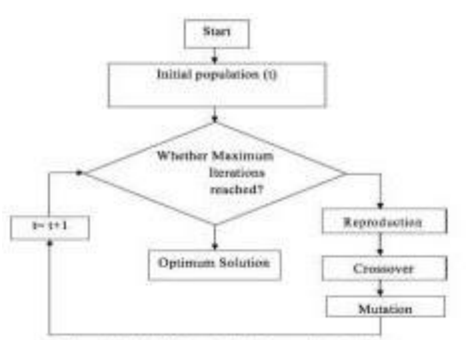


Figure 1.1 Working principle of a genetic algorithm

### 1.2 METHODOLOGY OF FIXTURE LAYOUT OPTIMIZATION

In GA based fixture layout optimization problem, at first, the selection of feasible regions for all fixture elements is done. Then the initial population (i. e. 30 sets of fixture layouts) is taken for GA. After the crossover and mutation, new fixture layouts are formed and corresponding moment values are found. The optimum fixture layout is the one which has the minimum moment among others and the corresponding workpiece deformation is found by ANSYS. Figure 1.2 shows the flow diagram of the GA based fixture layout optimization problem.

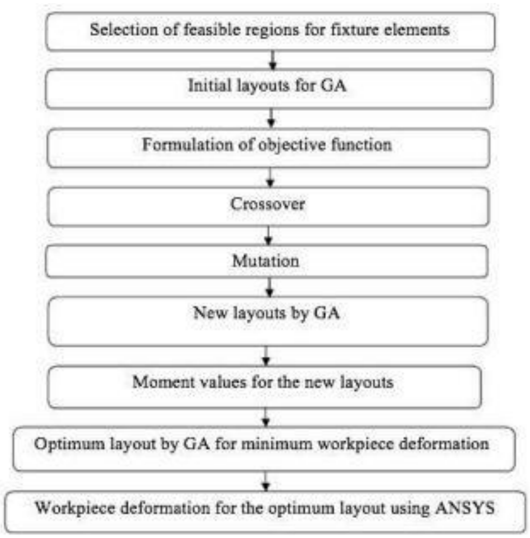


**Figure 1.2 Flowchart for fixture layout optimization using GA**

## 1.3 ILLUSTARTION OF FIXTURE LAYOUT OPTIMIZATION USING GA

The workpiece-fixture configuration for the end milling operation. The GA based fixture layout optimization method. Some random values from the ranges of design variables are considered and 30 sets of initial population are generated as shown in Table 1.1. A MATLAB program has been written to execute GA for this fixture layout optimization problem. The values of GA parameters such as crossover probability, mutation probability and the number of iterations have been varied and better GA parameters are selected for lesser amount of moment values. The selected GA parameters are given as Number of iterations (Nmax): 150 Population size (Ps) : 30 Crossover probability (Pc) : 60% Mutation probability (Pm): 4%

**Table 7.1 Initial population for GA**

| S.No. | Position of fixture elements along particular axis (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ | $L_6$ | $C_1$ | $C_2$ | $C_3$ |
| 1. | 104.21 | 42.68 | 18.12 | 78.67 | 93.74 | 33.79 | 32.23 | 19.15 | 17.36 |
| 2. | 74.88 | 21.10 | 15.77 | 120.15 | 75.91 | 22.89 | 42.23 | 38.09 | 38.09 |
| 3. | 85.55 | 32.01 | 66.80 | 73.72 | 117.28 | 42.39 | 60.39 | 95.71 | 44.05 |
| 4. | 75.51 | 40.41 | 93.37 | 111.08 | 119.32 | 18.22 | 34.66 | 13.13 | 63.68 |
| 5. | 77.73 | 48.75 | 109.94 | 113.14 | 97.31 | 39.87 | 100.34 | 109.39 | 59.27 |
| 6. | 109.32 | 51.73 | 23.90 | 115.63 | 97.23 | 17.98 | 30.84 | 88.15 | 72.27 |
| 7. | 103.73 | 33.80 | 70.86 | 77.60 | 89.88 | 26.03 | 34.17 | 62.28 | 71.38 |
| 8. | 87.29 | 16.03 | 60.22 | 92.89 | 117.15 | 37.21 | 28.27 | 71.90 | 33.02 |
| 9. | 114.83 | 16.49 | 11.27 | 86.10 | 91.41 | 43.94 | 34.36 | 35.39 | 58.14 |
| 10. | 75.00 | 21.20 | 46.07 | 112.30 | 78.89 | 13.53 | 56.62 | 59.10 | 23.63 |
| 11. | 92.59 | 46.57 | 27.35 | 94.42 | 111.34 | 50.43 | 43.29 | 113.05 | 12.10 |
| 12. | 90.10 | 21.06 | 94.99 | 117.67 | 92.40 | 43.74 | 108.80 | 68.51 | 61.27 |
| 13. | 106.80 | 45.42 | 43.30 | 82.32 | 85.22 | 31.18 | 56.03 | 65.76 | 44.45 |
| 14. | 108.09 | 20.59 | 66.55 | 86.29 | 93.09 | 28.96 | 29.78 | 34.78 | 43.07 |
| 15. | 81.63 | 50.42 | 27.72 | 80.56 | 78.18 | 29.44 | 106.82 | 62.31 | 72.34 |
| 16. | 94.80 | 25.22 | 74.41 | 80.10 | 79.90 | 23.33 | 114.83 | 76.77 | 52.02 |
| 17. | 92.88 | 18.55 | 38.14 | 115.66 | 119.19 | 32.12 | 56.96 | 82.67 | 52.56 |
| 18. | 101.61 | 20.92 | 79.99 | 101.62 | 119.87 | 32.22 | 21.89 | 52.32 | 69.22 |
| 19. | 104.36 | 36.80 | 83.75 | 100.17 | 101.40 | 45.57 | 37.61 | 49.32 | 65.50 |
| 20. | 106.33 | 30.59 | 90.05 | 80.53 | 76.40 | 44.58 | 53.73 | 115.71 | 49.74 |
| 21. | 85.51 | 25.30 | 58.21 | 114.87 | 84.89 | 38.03 | 73.65 | 14.04 | 22.60 |
| 22. | 103.07 | 46.14 | 18.97 | 103.67 | 90.63 | 26.47 | 38.06 | 104.71 | 26.53 |
| 23. | 102.00 | 35.46 | 34.50 | 90.52 | 113.33 | 45.30 | 74.50 | 107.72 | 71.08 |
| 24. | 80.57 | 33.91 | 107.73 | 98.39 | 74.25 | 33.18 | 86.10 | 95.19 | 11.98 |
| 25. | 78.68 | 49.90 | 26.30 | 92.99 | 75.59 | 25.26 | 33.73 | 20.56 | 43.75 |
| 26. | 95.18 | 22.43 | 98.36 | 77.18 | 81.70 | 50.85 | 22.56 | 38.02 | 21.57 |
| 27. | 115.25 | 42.94 | 67.60 | 85.14 | 104.98 | 48.10 | 41.74 | 45.88 | 77.43 |
| 28. | 88.31 | 42.79 | 116.59 | 79.48 | 108.99 | 33.93 | 44.11 | 82.73 | 59.10 |
| 29. | 98.96 | 26.55 | 18.36 | 82.42 | 104.92 | 37.08 | 55.39 | 24.61 | 44.48 |
| 30. | 83.24 | 34.70 | 57.37 | 85.14 | 95.37 | 35.54 | 64.34 | 87.17 | 42.46 |

1.3.1 Objective Function for GA During machining, the excess amount of imbalanced moment is one among the main factors influencing workpiece deformation. The

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balanced moment ensures better placement of fixture elements and provides better constraints over the workpiece to avoid deformation. Hence, the minimization of moment is taken as the objective. Nine sets of moment equations are formulated to obtain the moment values at locators and clamps. These equations are framed with the basic rule that the moment equals the force applied, multiplied by the distance from which it is applied. The following Equations from (1.1) to (1.9) are given as objective function to the MATLAB program and the new set of layouts are obtained by crossover and mutation and the corresponding moment values are found.

$$\sum ML_1 = \left[\begin{array}{l} -[(ZL_1 - ZL_2)R_3] - [(XL_1 - XL_2)R_3] \\ +[(ZL_1 - ZL_4)R_4] + [(XL_4 - XL_1)R_4] \\ +[(XL_5 - XL_1)R_5] + [(XL_6 - XL_1)R_6] \\ +[(ZL - ZL)R] + [(XC - XL)C^F] \\ +[(ZC - ZC)C^F] - [(ZL - ZC)C^F] \\ -[(XC - XL)C^F] - [(Z - ZL)F] \\ -[(X_F - XL_1)F_Y] - [(Z_F - ZL_1)F_Y] \\ +[(X_F - XL_1)F_Z] \end{array}\right] \qquad (1.1)$$

$$\sum ML_2 = \left[\begin{array}{l} [(ZL_1 - ZL_2)R_1] - [(XL_3 - XL_2)R_3] \\ -[(XL_4 - XL_2)R_4] + [(ZL_4 - ZL_2)R_4] \\ -[(XL_5 - XL_2)R_5] - [(ZL_5 - ZL_2)R_5] \\ -[(XL_6 - XL_2)R_6] - [(ZL_6 - ZL_2)R_6] \\ +[(XC - XL)C^F] - [(ZC - ZL)C^F] \\ -[(XC_3 - XL_2)C_3^F] + [(ZC_3 - ZL_2)C_3^F] \\ -[(Z_F - ZL_2)F_X] - [(X_F - XL_2)F_Y] \\ -[(Z_F - ZL_2)F_Y] + [(X_F - XL_2)F_Z] \end{array}\right] \qquad (1.2)$$

$$\sum ML_3 = \left[\begin{array}{l} [(ZL_1 - ZL_3)R_1] + [(ZL_2 - ZL_3)R_2] \\ +[(XL_4 - XL_3)R_4] - [(ZL_3 - ZL_4)R_4] \\ +[(XL_5 - XL_3)R_5] - [(ZL_5 - ZL_3)R_5] \\ -[(XL_3 - XL_6)R_6] - [(ZL_6 - ZL_3)R_6] \\ -[(ZC_2 - ZL_3)C_2^F] + [(XL_3 - XC_3)C_3^F] \\ + ZC - ZL\ C^F + [(Z - ZL)F] \\ -[(X_F - XL_3)F_Y] + [(Z_F - ZL_3)F_Y] \\ +[(X_F - XL_3)F_Z] \end{array}\right] \qquad (1.3)$$

$$\sum ML_4 = \left[\begin{array}{l} [(ZL_1 - ZL_4)R_1] + [(XL_4 - XL_3)R_3] \\ -[(ZL_5 - ZL_4)R_5] - [(XL_4 - XL_6)R_6] \\ -[(ZL - ZL)R] - [(XL - XC)C^F] \\ -[(ZC_2 - ZL_4)C_2^F] + [(XL_4 - XC_3)C_3^F] \\ +[(ZC - ZL)C^F] - [(Z - ZL)F] \\ +[(Z_F - ZL_4)F_X] + [(X_F - XL_4)F_Z] \end{array}\right] \qquad (1.4)$$

$$\sum ML_5 = \left[\begin{array}{l} -[(ZL_3 - ZL_2)R_2] + [(XL_5 - XL_3)R_3] \\ +[(ZL_5 - ZL_4)R_4] - [(XL_5 - XL_6)R_6] \\ -[(ZL - ZL)R] - [(XL - XC)C^F] \\ +[(ZL_5 - ZC_2)C_2^F] + [(XL_5 - XC_3)C_3^F] \\ -[(ZL - ZC)C^F] - [(Z - ZL)F] \\ +[(Z_F - ZL_5)F_Y] + [(X_F - XL_5)F_Z] \end{array}\right] \qquad (1.5)$$

$$\sum ML_6 = \left[\begin{array}{l} [(ZL_1 - ZL_6)R_1] - [(ZL_6 - ZL_2)R_2] \\ -[(XL_3 - XL_6)R_3] + [(XL_4 - XL_6)R_4] \\ +[(ZL_6 - ZL_4)R_4] + [(XL_5 - XL_6)R_5] \\ -[(ZL - ZL)R] + [(XC - XL)C^F] \\ -[(ZC - ZL)C^F] - [(Z - ZL)F_X] \\ +[(X_F - XL_6)F_Y] + [(Z_F - ZL_6)F_Y] \\ [(X_F - XL_6)F_Z] \end{array}\right] \qquad (1.6)$$

$$\sum MC_1 = \left[\begin{array}{l} -[(ZC_1 - ZL_1)R_1] - [(ZC_1 - ZL_2)R_2] \\ +[(XL_4 - XC_1)R_4] + [(ZC_1 - ZL_4)R_4] \\ +[(ZC_1 - ZL_5)R_5] - [(XC_1 - XL_6)R_6] \\ +[(ZC - ZL)R] + [(ZC - ZC)C^F] \\ +[(XC - XC)C^F] - [(ZC - ZC)C^F] \\ [(X_F - XC_1)F_Y] - [(ZC_1 - Z_F)F_Y] \\ +[(XC_1 - X)F] \end{array}\right] \qquad (1.7)$$

$$\sum MC_2 = \left[\begin{array}{l} [(ZL_1 - ZC_2)R_1] - [(ZC_2 - ZL_2)R_2] \\ +[(XC_2 - XL_3)R_3] - [(XC_2 - XL_4)R_4] \\ +[(ZC_2 - ZL_4)R_4] - [(XC_2 - XL_5)R_5] \\ -[(XC_2 - XL_6)R_6] - [(XC_2 - XC_1)C_1^F] \\ +[(XC_2 - XC_3)C_3^F] - [(Z_F - ZC_2)F_X] \\ +[(XC_2 - X_F)F_Y] + [(Z_F - ZC_2)F_Y] \\ -[(XC_2 - X_F)F_Z] \end{array}\right] \qquad (1.8)$$

$$\sum MC_3 = \left[\begin{array}{l} [(ZL_1 - ZC_3)R_1] - [(ZC_3 - ZL_2)R_2] \\ -[(XL_3 - XC_3)R_3] + [(XL_4 - XC_3)R_4] \\ +[(ZC_3 - ZL_4)R_4] + [(XL_5 - XC_3)R_5] \\ -[(ZL_5 - ZC_3)R_5] - [(XL_6 - XC_3)R_6] \\ +[(ZC - ZL)R] + [(XC - XC)C^F] \\ -[(Z_F - ZC_3)F_X] + [(X_F - XC_3)F_Y] \\ +[(Z_F - ZC_3)F_Y] + [(X_F - XC_3)F_Z] \end{array}\right] \qquad (1.9)$$

***where***

$\sum ML_1$ to $\sum MC_3$ represent the moment values about the six locators and three clamps in Nmm R1 to R6 represent the reaction forces at locator positions L1to L6 in N XL1 to ZC3 represent the coordinate values of the position ofthe corresponding locators and clamps about the particular axis in mm. One hundred and fifty iterations are carried out and fixture layouts for minimum moment values are selected among them. The layouts for minimum moment values are shown in Table 1.2.

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Table 1.2 New fixture layouts and moment values by GA

| S.No. | Position of fixture elements along particular axis (mm) | | | | | | | | | Moment |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ | $L_6$ | $C_1$ | $C_2$ | $C_3$ | (Nmm) |
| 1. | 99.3 | 37.2 | 21.5 | 84.1 | 95.1 | 28.6 | 105.4 | 59.5 | 74.8 | 375.33 |
| 2. | 100.0 | 50.3 | 34.6 | 105.7 | 84.0 | 31.8 | 64.8 | 79.8 | 75.2 | 94.92 |
| 3. | 95.2 | 23.3 | 15.2 | 75.5 | 102.4 | 16.2 | 100.4 | 47.2 | 59.2 | 723.20 |
| 4. | 98.5 | 26.2 | 10.8 | 96.5 | 109.6 | 27.9 | 82.8 | 86.7 | 46.4 | 876.0 |
| 5. | 79.1 | 44.3 | 11.8 | 78.0 | 94.4 | 36.5 | 30.1 | 27.4 | 73.2 | 89.34 |
| 6. | 82.5 | 52.4 | 23.9 | 98.7 | 108.9 | 26.3 | 20.6 | 53.6 | 60.2 | 294.08 |
| 7. | 76.3 | 34.8 | 12.0 | 105.9 | 93.9 | 13.5 | 99.3 | 101.6 | 29.4 | 213.07 |
| 8. | 81.1 | 37.7 | 27.6 | 99.0 | 94.4 | 13.6 | 95.1 | 42.6 | 72.5 | 133.1 |

### 1.3.2 Optimum Layout by GA

Table 1.3 presents the optimal layout obtained from GA for minimum moment value and the deformation value obtained in ANSYS. Figure 1.3 also indicates the workpiece deformation value for the layout corresponding to minimum moment. Here, Dmax represents the maximum workpiece deformation for the corresponding fixture layout.

Table 1.3 Optimum layout of GA

| Position of fixture elements along particular axis (mm) | | | | | | | | | $D_{max}$ |
|---|---|---|---|---|---|---|---|---|---|
| $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ | $L_6$ | $C_1$ | $C_2$ | $C_3$ | (mm) |
| 79.1 | 44.3 | 11.8 | 78.0 | 94.4 | 36.5 | 30.1 | 27.4 | 73.2 | 0.046861 |

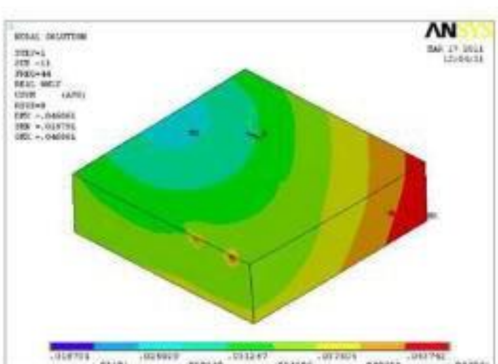


Figure 1.3 Workpiece deformations for optimum layout of GA

The final optimal model given by GA for the workpiece-fixture configuration gives the maximum workpiece deformation of 0.046861 mm. For the same workpiece-fixture configuration, the final optimal model given by ANN reports the maximum deformation of 0.046812 mm. By comparing the results of ANN and GA, ANN reports only 0.1% reduction in workpiece deformation. So the performances of ANN and GA are nearly equal in this fixture layout optimization problem.

## 1.4FINETUNING OF GA BASED OPTIMUM LAYOUT

Finetuning is based on the variation of deformation values for various positions of locators and clamps. The positions of the locators and clamps are rearranged to minimize workpiece deformation by keeping the GA based optimum layout as initial layout. Figures from 1.4(a) to 1.4(i) show the variation of workpiece deformation for various positions of locators and clamps. The middle position of L1 and final portion of L2 give 0.04518 mm deformation as shown in Figures 1.4(a) and 1.4(b). The influence of positions of L3 and L4 do not have any impact on minimum workpiece deformation and it is 0.04518 mm as shown in Figures 1.4(c) and 1.4(d).

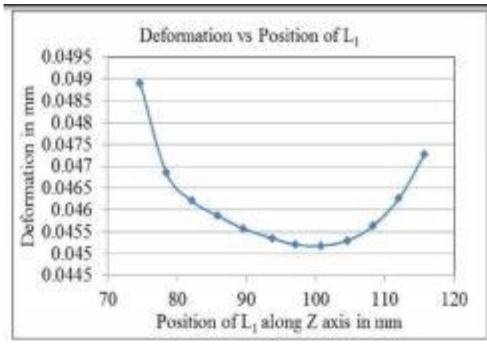



Figure 1.4(a) Position of locator $L_1$ vs workpiece deformation

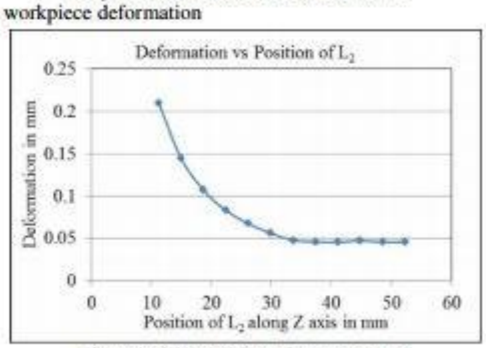



Figure 1.4(b) Position of locator $L_2$ vs workpiece deformation

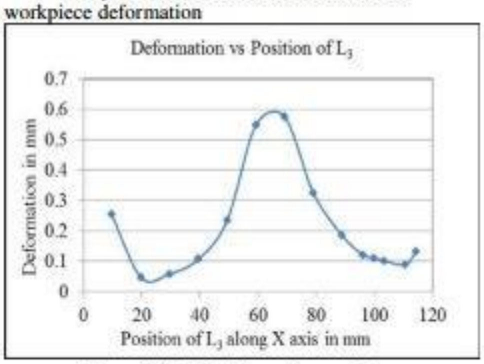
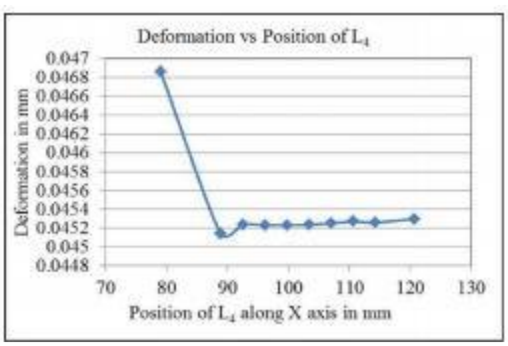



Figure 1.4(c) Position of locator $L_3$ vs workpiece deformation



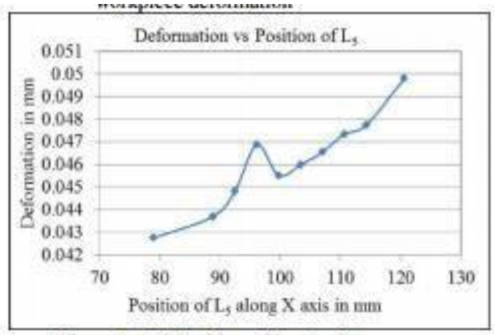




Figure 1.4(e) Position of locator $L_5$ vs workpiece deformation

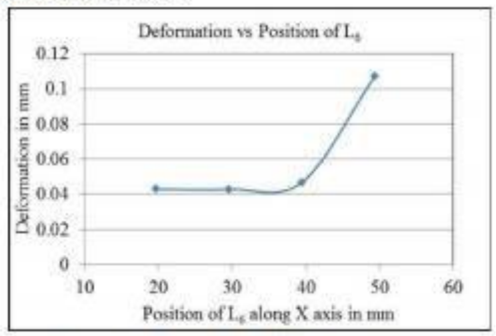



Figure 1.4(f) Position of locator $L_6$ vs workpiece deformation

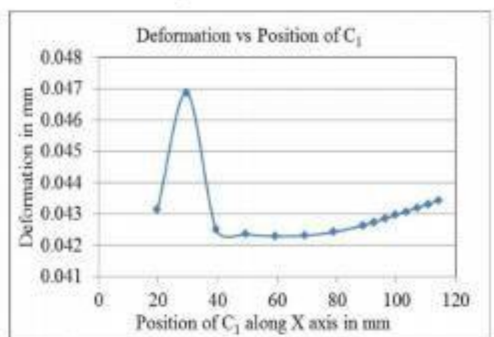



Figure 1.4(g) Position of clamp C1 vs workpiece deformation

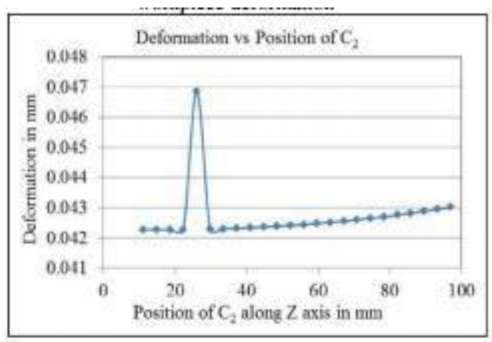



Figure 1.4(h) Position of clamp $C_2$ vs

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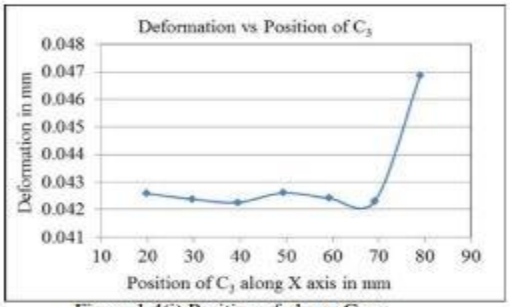

Figure 1.4(i) Position of clamp $C_3$ vs workpiece deformation

Figure 1.4(e) shows minimum deformation occurs when the position of L5 is at 79.02 mm and the corresponding deformation is 0.042745 mm. This indicates position of L5 has more influence on minimizing deformation than other fixture elements. Figure 1.4(f) shows the same minimum deformation of 0.042745 mm that occurs when L6 is at 29.63 mm. For clamps C1 and C2, Figures 1.4(g) and 1.4(h) also show the same minimum deformation of 0.042745 mm and for C3, the minimum deformation is 0.042259 mm which is shown in Figure 7.4(i). Based on the graphical results, the optimum fixture layout by GA is finetuned to the new fixture layout which is given in Table 1.4

Table 1.4 Refined optimum layout of GA

| Position of fixture elements along particular axis (mm) | | | | | | | | | $D_{max}$ |
|---|---|---|---|---|---|---|---|---|---|
| $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ | $L_6$ | $C_1$ | $C_2$ | $C_3$ | (mm) |
| 100.8 | 41.0 | 11.8 | 88.9 | 79.0 | 29.6 | 59.2 | 14.9 | 39.5 | 0.042259 |

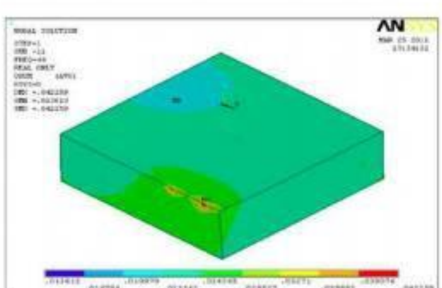
Figure 1.5 Workpiece deformations for the refined optimum layout of GA

The refined optimum layout gives 0.042259 mm of workpiece deformation which is shown in Figure 1.5 and it has 9.8% less deformation compared to earlier GA based optimum layout.

## 1.5 METHODOLOGY OF FIXTURE LAYOUT OPTIMIZATION USING GA-ANN

The performances of ANN and GA are nearly equal in this fixture layout optimization problem. To get better results, the GA-ANN approach has been introduced in the fixture layout optimization problem. In GA-ANN based optimization procedure, new fixture layouts generated by GA using the variable bounds are fed as input to ANN and the maximum deformation of the each fixture layout is found by ANN. Previously, ANN is trained and tested with sufficient sets of fixture layouts and corresponding workpiece deformations. The optimal fixture layout is the one which shows the minimum deformation among others. The results obtained by using GA and GA-ANN are compared and the final optimum layout is selected. Figure 1.5 shows the methodology flow chart for the GA-ANN based optimization.

## 1.6 ILLUSTRATION OF FIXTURE LAYOUT OPTIMIZTION USING GA AND ANN

In this section, ANN is introduced as another optimization tool along with GA and the results obtained by GA-ANN are compared with the results obtained by GA to know which particular methodology is best suited for fixture layout optimization problem using GA-ANN

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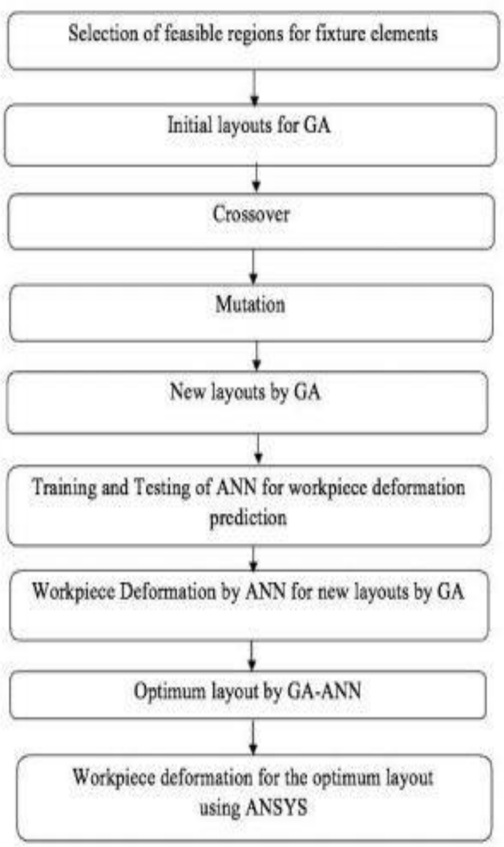


**Figure 1.6 Flowchart for fixture layout optimization using GA-ANN**

The same initial population shown in Table 1.1 is considered again. With the same GA parameters, iterations are carried out for new fixture layouts. Here the trained and tested ANN is used to find the workpiece deformation for the given layout. To train the ANN, 100 sets of fixture layouts and corresponding workpiece deformations obtained by FEM are fed to the ANN system. Then the new fixture layouts generated by GA are given as input to ANN and the maximum workpiece deformation for each fixture layout is found out by using ANN. Finally, the layout which shows the minimum deformation has been selected as optimal fixture layout.

### 1.6.1 Optimum Layout and Minimum Deformation by GA- ÅNN

Better fixture layouts given by GA and correspondingworkpiece deformation values predicted by ANN are given in Table 1.5.

**Table 1.5 Fixture layouts and Deformation values from GA-ANN**

| S.No. | Position of fixture elements along particular axis (mm) | | | | | | | | | $D_{max}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ | $L_6$ | $C_1$ | $C_2$ | $C_3$ | (mm) |
| 1. | 76.1 | 42.1 | 29.9 | 74.1 | 116.5 | 45.4 | 10.6 | 80.5 | 22.5 | 0.213 |
| 2. | 88.9 | 11.2 | 25.8 | 107.9 | 102.4 | 53.3 | 22.8 | 78.4 | 22.2 | 0.108 |
| 3. | 73.8 | 31.7 | 47.0 | 92.3 | 82.7 | 61.4 | 36.8 | 59.4 | 30.4 | 0.999 |
| 4. | 78.7 | 22.2 | 41.8 | 121.4 | 88.5 | 52.4 | 38.8 | 95.5 | 34.6 | 0.093 |
| 5. | 90.1 | 37.4 | 21.3 | 111.0 | 81.1 | 43.0 | 86.5 | 18.3 | 53.0 | 0.041 |

Among the five layouts, the one which shows minimum deformation is selected as optimal layout, shown in Table 1.6. The workpiece deformation value for the optimum layout predicted by ANN is 0.0412 mm and for the same layout workpiece deformation found by ANSYS is 0.043176 mm and is shown Figure 1.7.

**Table 1.6 Optimum layout of GA-ANN**

| Position of fixture elements along particular axis (mm) | | | | | | | | | $D_{max}$ |
|---|---|---|---|---|---|---|---|---|---|
| $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ | $L_6$ | $C_1$ | $C_2$ | $C_3$ | (mm) |
| 90.1 | 37.4 | 21.3 | 111.0 | 81.1 | 43.0 | 86.5 | 18.3 | 53.0 | 0.043176 |

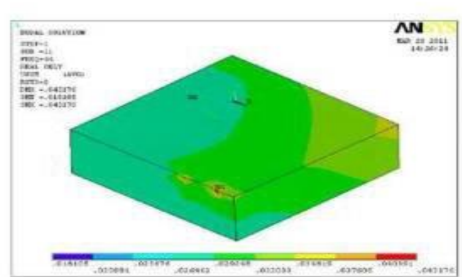

**Figure 1.7 Workpiece deformations for the optimum layout of GA-ANN**

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**1.7 FINE TUNING OF GA-ANN BASED OPTIMUM LAYOUT** The following graphs in Figures 1.8(a) to 1.8(i) exemplify the variations of deformation values for various positions of locators and clamps and the new coordinate values of fixture elements are selected for least workpiece deformation. Figure 1.8(a) denotes that the new position of L1 gives 0.043007 mm deformation and refined position of L2 produces 0.042997 mm deformation as shown in Figure 1.78b). Changes in positions of locators L3, L4 and L5 do not yield better results and they produce almost the same deformation of 0.042997 mm, shown in Figures 1.8(c), 1.8(d) and 1.8(e). The refined position of locator L6 reports less deformation of 0.042278 mm as shown in Figure 1.8(f). Figures 1.8(g), 1.8(h) and 1.8(i) show clamps C1, C2 and C3 minimizing little amount of deformation and the final deformation after refining the position of C3 is 0.041983 mm

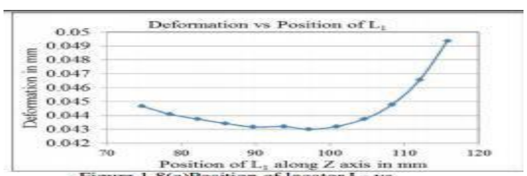


Figure 1.8(a)Position of locator $L_1$ vs workpiece deformation

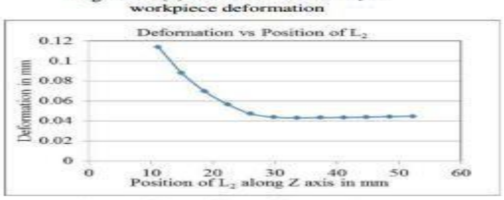


Figure 1.8(b)Position of locator $L_2$ vs workpiece deformation

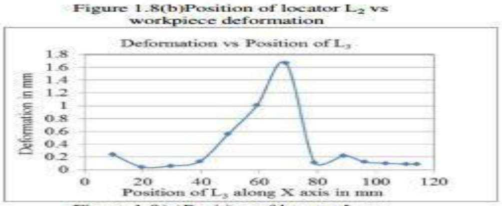


Figure 1.8(c)Position of locator $L_3$ vs workpiece deformation

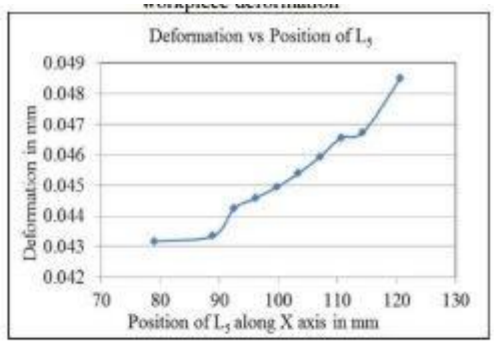


Figure 1.8(e)Position of locator $L_5$ vs workpiece deformation

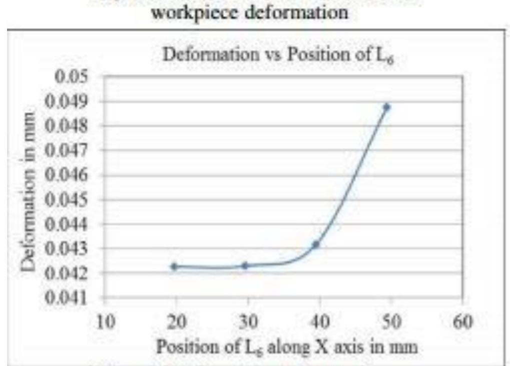


Figure 1.8(f)Position of locator $L_6$ vs workpiece deformation

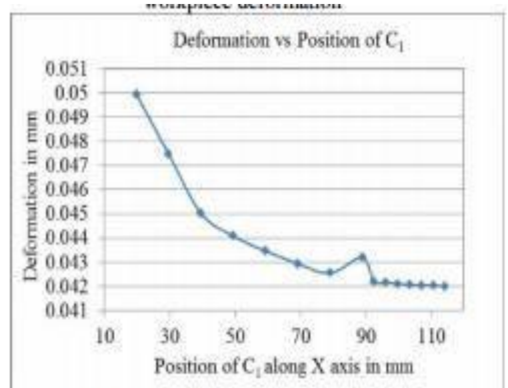


Figure 1.8(g)Position of Clamp $C_1$ vs workpiece deformation

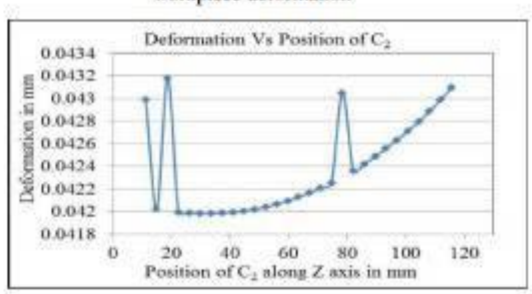


Figure 1.8(h)Position of Clamp $C_2$ vs workpiece deformation

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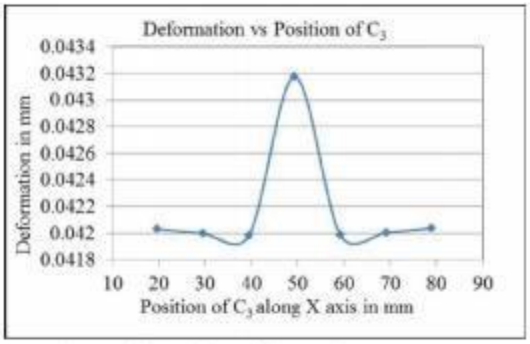


Figure 1.8(i)Position of Clamp $C_3$ vs workpiece deformation

Table 1.7 presents the refined optimum fixture layout and corresponding workpiece deformation for the layout by ANSYS is shown in Figure 1.8. The refined GA-ANN based optimum layout reduces 2.8% of workpiece deformation compared with the deformation of the prioroptimized layout and it gives 0.65% reduction in deformation compared to deformation of finetuned optimum layout by GA.

Table 1.7 Refined optimum layout of GA-ANN

| Position of fixture elements along particular axis (mm) | | | | | | | | | $D_{max}$ |
|---|---|---|---|---|---|---|---|---|---|
| $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ | $L_6$ | $C_1$ | $C_2$ | $C_3$ | (mm) |
| 97.1 | 33.6 | 19.7 | 120.6 | 79.0 | 19.7 | 114.3 | 29.8 | 39.5 | 0.041983 |

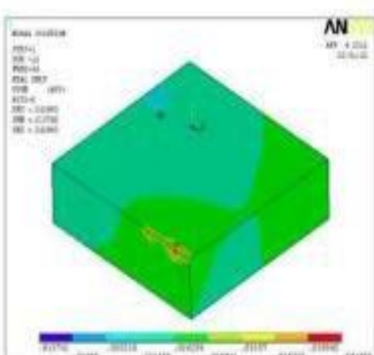

Figure 1.9 Workpiece deformations for the refined optimum layout of GA-ANN

## CONCLUSION

In this chapter, GA based and GA-ANN based procedures are presented for optimizing the fixture layout during a machining operation. Here the objective function of GA is the minimization of moment values at all locators and clamps. The corresponding fixture layout for minimummoment is the optimal layout and it gives minimum workpiece deformation. The minimum workpiece deformation for the optimal layout has been found by FEM. By comparing the results of GA and ANN, ANN reports only 0.1% reduction in workpiece deformation. So the performances of ANN and GA are nearly equal in this fixture layout optimization problem. In the GA-ANN based optimization procedure, first the ANN is trained with sufficient sets of fixture layouts and corresponding workpiece deformations by FEM.After the testing process, the resulting fixture layouts generated by GA are given as input to ANN and the maximum workpiece deformation for each fixture layout is found out by using ANN. The fixture layout which shows the minimum deformation among others is the optimal one. The predicted workpiece deformation for optimum layout by ANN is verified by comparing it with the result of FEA, which shows a reasonable agreement. By comparing the results obtained by GA and the GA-ANN, the optimal fixture layout obtained by the GAANN gives 7.86% reduction in workpiece deformation than the layout obtained by GA. Compared to deformation of optimum layout by ANN-

DOE, 2.12% reduction in deformation is achieved by the optimal fixture layout given by the GA-ANN. This shows the GA-ANN based optimization is superior to the GA based and ANN-DOE based optimization methods.

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