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DESIGN AND OPTIMIZATION OF MACHING FIXTURE LAYOUT USING ANN AND DOE

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ABSTRACT—Since the range of design variables for the fixture layout optimization problems is much wider, the consideration of all the possible combinations of fixture layouts within the range of design variables is more complex in ANN. The maximum number of in between values that could be considered in a total range of design variable is five. For the five values, 59 combinations of layouts are formed. So, the fixture layout which gives the minimum deformation by ANN is a better layout among the considered values only. ANN will give more optimized results if the range of the design variable is smaller and the same may be the solution region. Many researchers have combined ANN with some other optimization tool to get better results. A hybrid fuzzy logic-ANN algorithm has been used for fault detection and isolation in robot manipulators and a hybrid optimization using ANN and GA has been used for joining process of plastics, with selection of dominant factors through Taguchi method. Taguchi method is also used to analyze the effect of each parameter on the machining characteristics of electro-discharge machining (EDM) and yields fruitful results. Along with ANN, Taguchi method is used to predict tensile strength of FSW A319 alloy and surface roughness of drilled holes So, along with ANN, Design of Experiments (DOE) is introducted in this fixture layout optimization to find the solution reason from the wide range of design variables.

Keywords— clamp;fixture layouts;

1. INTRODUCTION

1.1 DESIGN OF EXPERIMENTS DOE is a structured and organized method used to determine the relationship between the different factors affecting a process and the output of that process. This is a method for quantitatively identifying the right inputs and parameter levels for getting a desired output. The marriage of DOE with optimization of control parameters to obtain the best results is achieved by the Taguchi Method. Taguchi method involves reducing the variation in a process through robust design of experiments. The prime advantage of employing DOE through Taguchi method is the reduction in the number of experimental or simulation runs required togenerate sufficient information for a statistically adequate result. The Signal-to-Noise ratio for smaller-thebetter is used for situations where the target value is zero. The equation is S/Ns= -10log10 (Mean Standard Deviation). 1.2 METHODOLOGY The first step in the optimization procedure is to have sufficient sets of fixture layouts that are required to train the ANN and the maximum

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[Type text] Page 2 workpiece deformation of each fixture layout is found out by using FEM. The solution region for all design variables to obtain minimum deformation of the workpiece is found by DOE.After the training process, the possible new fixture layouts within the solution region are found and fed to the ANN to predict the maximumdeformation value for each fixture layout.The optimal fixture layout is the one which shows the minimum deformation among others.

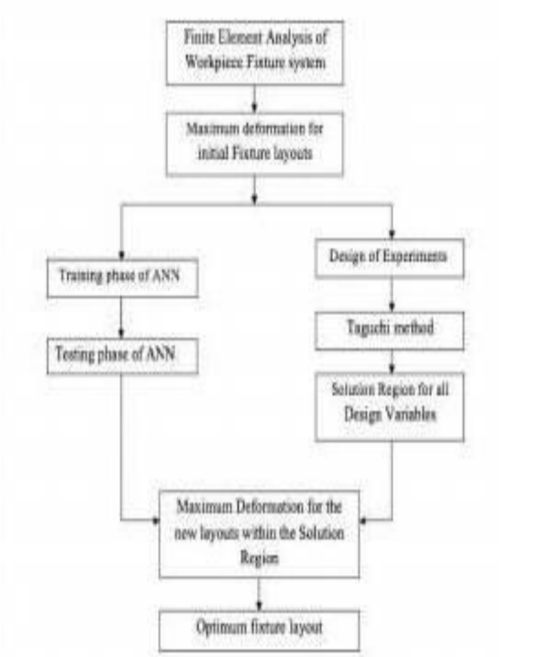

Figure 1.1 Flow chart for ANN-DOE based fixture layout optimization

Figure 1.1 shows the flow chart that brings methodology of the fixture layout optimization problem using ANN and DOE.

1.3ILLUSTRATION WITH CASE STUDY -1

1.3.1 Selection of Optimum Fixture Layout by DOE and ANN

More optimized results can be obtained in the fixture layout optimization problems if the range of the design variable is smaller and the same may be the solution region.So DOE with Taguchi method is introduced here to find the solution region from the wide range of design variables. In this fixture layout optimization problem, the range of nine design variables are divided into three levels namely 1, 2 and 3. Here 1, 2 and 3 indicate the initial, middle and final portions of a design variable range respectively. Instead of testing all possible combinations, the Taguchi method tests pairs of combinations which are known as orthogonal arrays. Taguchi's orthogonal arrays can be used to estimate main effects using only a few experimental or simulation runs.Proper orthogonal array can be selected by knowing the number of parameters and the number of levels. The L27 orthogonal array for nine variables with three levels given by the DOE software Minitab is shown in Figure 1.2. This orthogonal array represents 27 different positions of fixture elements where, L1 to L6 represents locator positions and C1 to C3 represents clamp positions.Based on the L27 orthogonal array, 27 new fixture layouts with suggested locations of fixture elements have been formed and fed to the trained ANN to predict the maximum deformation value for each fixture layout. Then the 27 fixture layouts and their corresponding maximum deformation values given by ANN are fed into the Minitab software to find the solution region for all design variables for minimum deformation of the work piece using smaller the better criteria in Taguchi method.

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L1	L2	L3	L4	L5	L6	C1	C2	C3
1	1	1	1	1	1	1	1	1
1	1	1	1	2	2	2	2	2
1	1	1	1	3	3	3	3	3
1	2	2	2	1	1	1	2	2
1	2	2	2	2	2	2	3	3
1	2	2	2	3	3	3	1	1
1	3	3	3	1	1	1	3	3
1	3	3	3	2	2	2	1	1
1	3	3	3	3	3	3	2	2
2	1	2	3	1	2	3	1	2
2	1	2	3	2	3	1	2	3
2	1	2	3	3	1	2	3	1
2	2	3	1	1	2	3	2	3
2	2	3	1	2	3	1	3	1
2	2	3	1	3	1	2	1	2
2	3	1	2	1	2	3	3	1
2	3	1	2	2	3	1	1	2
2	3	1	2	3	1	2	2	3
3	1	3	2	1	3	2	1	3
3	1	3	2	2	1	3	2	1
3	1	3	2	3	2	1	3	2
3	2	1	3	1	3	2	2	1
3	2	1	3	2	1	3	3	2
3	2	1	3	3	2	1	1	3
3	3	2	1	1	3	2	3	2
3	3	2	1	2	1	3	1	3
3	3	2	1	3	2	1	2	1

Figure 1.2 L_{27} Orthogonal array by Taguchi method

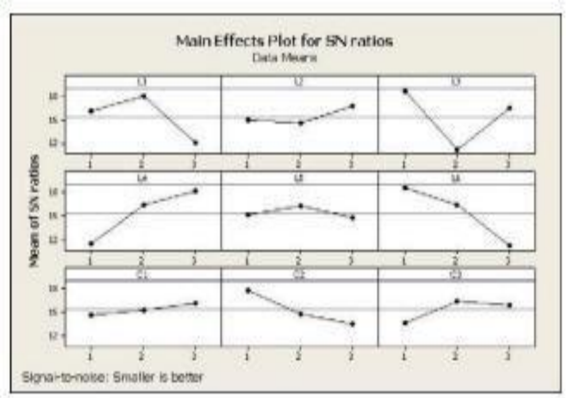

Figure 1.3 Solution regions for Design variables by DOE

Signal-to-Noise ratio values are predicted by analysing 27 fixture layouts and their corresponding deformation values. For lower workpiece deformations,the new reduced range of design variables corresponding to higher mean of SN ratios indicated by the Taguchi method is shown in Figure 1.3. The results of DOE in Figure 1.3 indicates that the solution regions for L1, L5 and C3 lay middle of their ranges and the solution regions for L2, L4 and C1 occur in the final portions of their ranges. The initial portions of ranges are selected as solution regions for L3, L6 and C2 as per the results given by DOE.

1.3.2 Formation of New Fixture Layouts in the solution Region

The solution region (i.e. the minimum and maximum value of each design variable) for each design variable obtained from the DOE is given as input to ANN. The number of variable values required within the range is also defined. If the division value is more, the number of variables within the range is also more. Increment value = (maximum-minimum) / Number of points Similarly increment value for each design variable is found out. The new set of variables is formed by adding the increment value to the minimum value of each design variable.Then the maximum deformation of the possible fixture layouts within the solution region is predicted by ANN. The optimal fixture layout and maximum deformation predicted by using DOE and ANN is shown in Table 1.1. Also the maximum deformation for the optimal layout is found by using FEA and is shown in Figure 1.4. It shows 5.77% reduction in deformation compared to deformation of optimum layout by ANN.

Table 1.1 Optimum fixture layout by DOE – ANN

Fixture Elements	Optimal position of fixture Elements (mm)			Maximum deformation of the workpiece (mm)	
	X	Y	Z	ANN	FEA
L_1	0.00	19.05	93.83	0.04231	0.04411
L_2	0.00	19.05	44.82		
L_3	19.76	19.05	0.00		
L_4	99.76	0.00	14.94		
L_5	79.02	0.00	112.06		
L_6	29.63	0.00	63.50		
C_1	103.41	19.05	127.00		
C_2	127.00	19.05	26.14		
C_3	29.63	38.1	63.50		

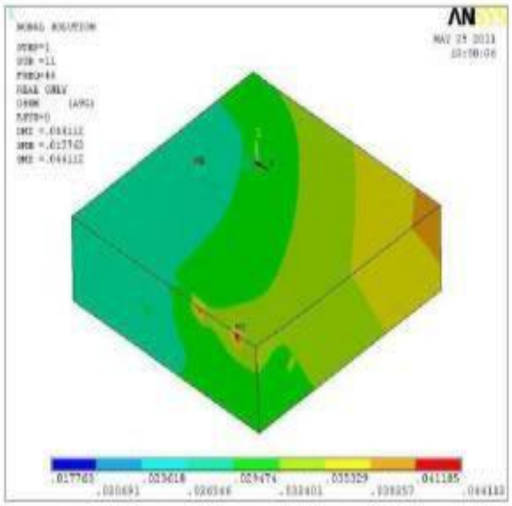

Figure 1.4 Workpiece deformations for optimum layout by ANN - DOE

1.4 FINETUNING OF ANN-DOE BASED OPTIMUM LAYOUT

In this section, the finetuning of the ANN-DOE based optimized layout is presented. Figure 1.5(a) shows that workpiece deformation is minimum with initial position of locator L1 and graph in Figure 1.5(b) shows the workpiece deformation gradually decreasing with the initial movement of [Type text] Page 4 L2.Minimum deformation of 0.0441 mm occurs when the position of L1 is at 74.7 mm and 0.04379 mm deformation is obtained when L2 is at 33.6 mm. In Figure 1.5(c), L3 reports the same deformation of 0.04379 mm as minimum at the position of 19.83 mm and in Figure 1.5(d), L4 at 114.3 mm induces 0.04374 mm workpiece deformation. As reported in the earlier finetuning of ANN layout, here also locators L5 and L6 report minimum deformations at initial positions which are shown in Figures 1.5(e) and 1.5(f).

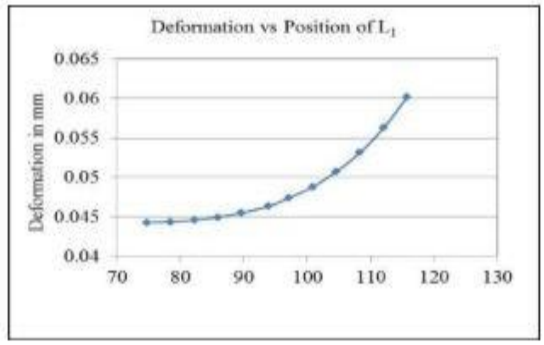

Figure 1.5 (a) Position of Locator L_1 vs workpiece deformation

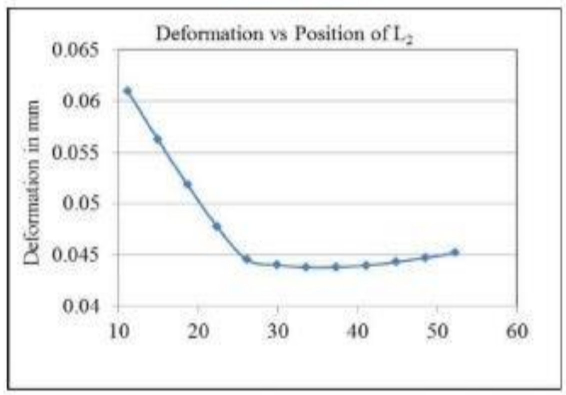

Figure 1.5 (b) Position of Locator L_2 vs workpiece deformation

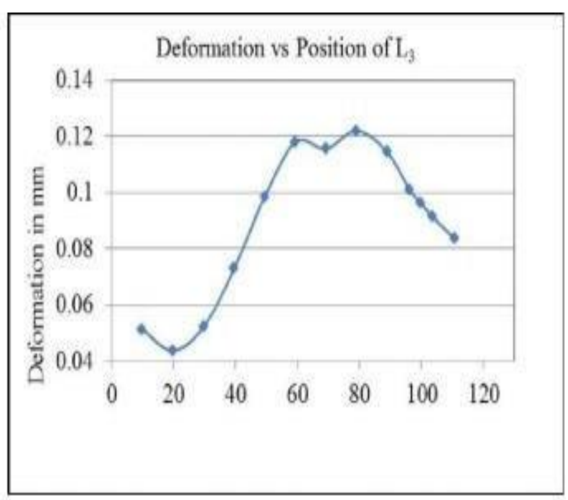

Figure 1.5 (c) Position of Locator L3 vs workpiece deformation

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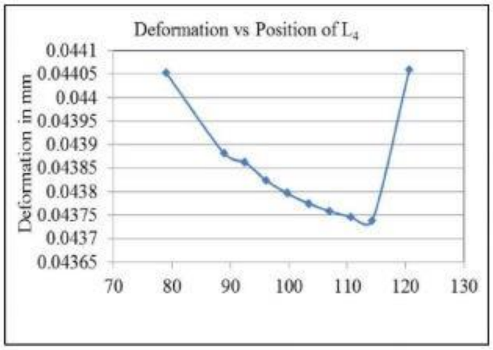

Figure 1.5 (d) Position of Locator L_4 vs workpiece deformation

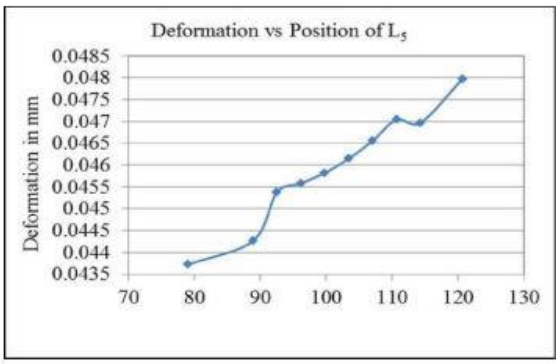

Figure 1.5 (e) Position of Locator L_5 vs workpiece deformation

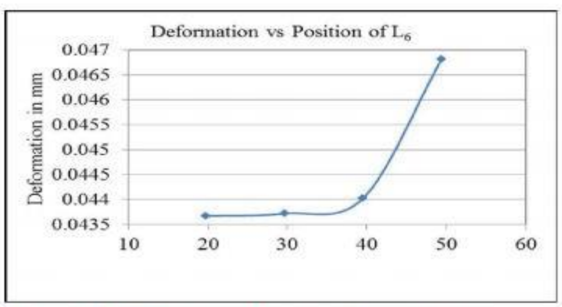

Figure 1.5 (f) Position of Locator L_6 vs workpiec deformation

Similar to ANN finetuned results, clamp C1 reports the least deformation at the final portion and C2, C3 report minimum deformations at the initial portions of their ranges which are shown in Figures 1.5(g), 1.5(h) and 1.5(i).The least deformations for C1, C2 and C3 are 0.04333 mm, 0.04327 mm and 0.04325 mm respectively. Refined optimum layout is shown in Table 1.2

where, Dmax represents maximum workpiece deformation.Figure 1.6 shows the workpiece deformation of 0.04325 mm for the refined layout and it shows 1.9% reduction in maximum workpiecedeformation compared to deformation of optimum layout before fine tuning.Here the position of locator L2 has more influence on minimum workpiece deformation than other fixture elements.

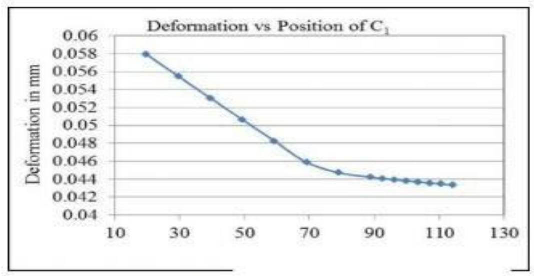

Figure 1.5 (g) Position of Clamp C_1 vs workpiece deformation

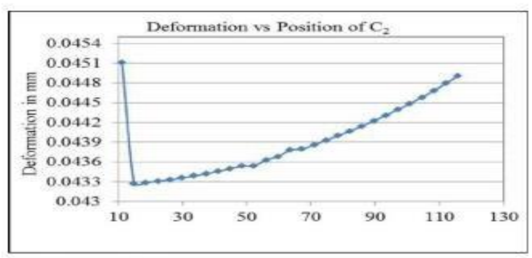

Figure 1.5 (h) Position of Clamp C_2 vs workpiece deformation

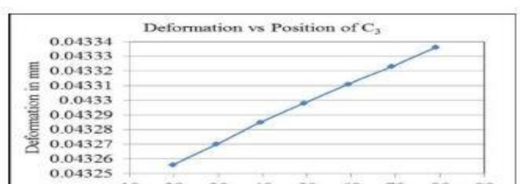

Figure 1.5 (i) Position of Clamp C_3 vs workpiece deformation

Table 1.2 Refined optimum fixture layout of ANN- DOE

Position of fixture Elements along Particular axis (mm)									D_{max} by FEM (mm)
L_1	L_2	L_3	L_4	L_5	L_6	C_1	C_2	C_3	
74.70	33.62	19.75	114.3	79.02	19.75	114.3	14.94	19.76	0.043256

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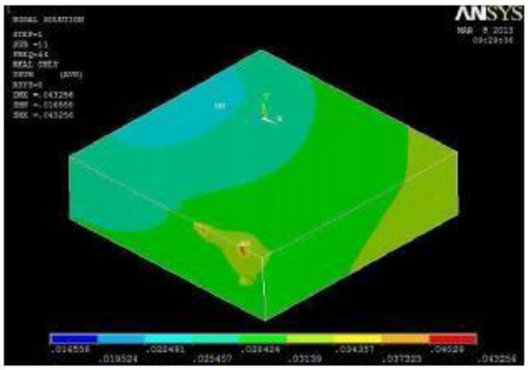

Figure 1.6 workpiece deformations for the refined optimum layout of ANN - DOE

1.5 ILLUSTRATION WITH CASE STUDY - 2

1.5.1 Selection of Optimum fixture layout by DOE and ANN

Similar to case study 1, the range of each and every design variable is divided into three smaller ranges namely 1, 2 and 3. The L27 orthogonal array for [Type text] Page 6 eight variables with three levels is developed by the DOE software Minitab using Taguchi method. Based on the L27 orthogonal array,the new 27 fixture layouts have been formed and fed to the trained ANN to predict the maximum deformation value for each fixture layout. Then the 27 fixture layouts and their corresponding maximum deformation values given by ANN are fed into the Minitab software to find the solution region for all design variables for minimum deformation of the workpiece using smaller-the-better criteria in Taguchi method.The solution regions for eight design variables obtained by DOE are shown in Figure 1.7 and it declares that the solution regions for L1, L4 and C2 lay middle of their ranges and the solution regions for L2, L3 and L6 occur in the final portions of their ranges.The initial portions of ranges are selected as solution regions for L5 and C1 as per the results given by DOE. The optimal fixture layout and maximum deformation predicted by using DOE and ANN is shown in Table 1.3 and Figure 1.8. The result shows 9.82% reduction in deformation compared to deformation of optimum layout by ANN.

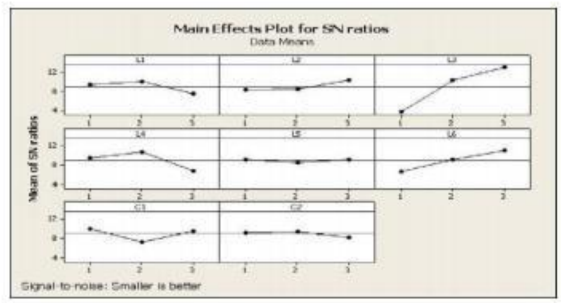

Figure 1.7Solution regions for design variables by DOE

Table 1.3Optimum fixture layout by ANN-DOE

Optimal Position of fixture Elements along Particular axis (mm)								D max (mm)	
L_1	L_2	L_3	L_4	L_5	L_6	C_1	C_2	ANN	FMM
39.56	135.61	81.23	24.25	95.60	95.60	46.94	81.33	0.0936	0.1053

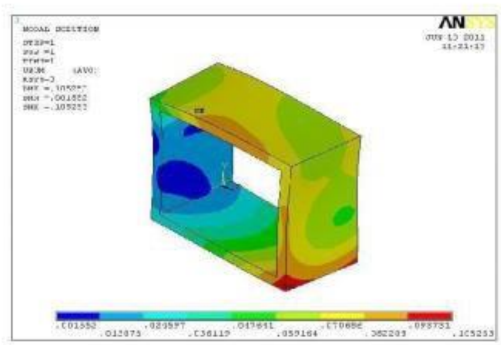

Figure 1.8 Deformation distributions for optimum layout of ANN - DOE

CONCLUSION

In this work, artificial intelligence and DOE based procedure is introduced for optimizing the fixture layout in a machining operation. ANN is trained with sufficient fixture layouts and their corresponding workpiece deformation, which are obtained from FEM. The trained ANN can predict the state of maximum elastic deformation of the workpiece. Then DOE is introduced as another optimization tool to find the solution region for all design variables for minimum deformation of workpiece. The feasible region given by DOE is given as the solution region for ANN. The maximum deformations of the possible fixture layouts within the solution region are predicted by ANN. The layout which shows the minimum deformation is selected as optimal fixture layout. The maximum deformation value of the optimal fixture layout is found out using FEA. The [Type text] Page 7 predicted result is verified by comparing it with the result of FEA, which shows a reasonable agreement.Compared to deformation of optimum fixture layout by ANN, the ANN-DOE approach reports 5.77% reduction in deformation for case study - 1 and shows 9.82% reduction in deformation for case study - 2. Thus it has been proved that the ANN-DOE approach is better than theANN approach for fixture layout optimization problems and it is clear that ANN-DOE approach can be used directly,where the DOE can be used first to find the solution regions.Then the ANN can be trained within the solution regions to reduce theconvergence time and achieve a better solution.

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