Optimization of Clamping Force in End Milling Fixture Using SFLA Alogorithm

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ABSTRACT

The complex part in fixture design for any machining process is the clamping scheme. To locate and to constrain a workpiece during machining operation the fixtures are used. An ideal fixture design exhibits minimal moment while machining. The purpose of this work is to design a fixture which provides minimum deformation to work piece in machining process. This can be achieved by selecting the optimal location of fixturing elements and clamping forces. In this work the clamping forces are taken in to account for minimizing deformation of the prismatic work piece made off aluminum 6061 during the end milling operation. Shuffled frog leaping algorithm is used for the optimization of the clamping force. The objective functions are formulated based on the equilibrium conditions of forces, moments and stick/slip conditions. Using these equations in shuffled frog algorithm the clamping force is optimized. Thus clamping forces satisfying constraints, along with its respective layout are solved for deformation values using ANSYS software. The layout which gives the minimum deformation value is selected as the fittest one. The minimum deformation achieved in this paper for the optimized clamping forces is 0.036961mm. So it is selected as the fittest clamping forces for fixture to hold the corresponding dimensional prismatic workpiece made of aluminum 6061 in end milling operation.

KEY WORDS: Aluminium 6061, ANSYS software.

1. INTRODUCTION

In machining process fixture is used to hold the workpiece. The fixture is a device which consists of locators and clamps. Locators are used to position the workpiece whereas the clamps are used to hold the workpiece under constraints. In general the coloumb law of friction is used as a principle to hold the workpiece. According to the principle the workpiece has to be arrested at least in 8 degrees of freedom. In this work for end milling process the fixture is optimized using shuffled frog leaping algorithm. The fixture scheme is changed with parameters like position of the locators and force applied by the clamps.

Shuffled Frog Leaping Algorithm: Shuffled frog leaping algorithm is an evolutionary biological natural mimic used for searching. This kind of algorithms are used to get the near optimum solution for complex problems. It has two searching techniques local search like “particle swam optimization” and mixed search like “shuffled complex evolution”. In this work the shuffled frog leaping algorithm is used for cluster analysis to get near optimum solution.

Literature Review: Kashya (1999), investigated the optimization and finite element analysis in design of fixture. Kulkanra Krishnakumar (2000), proposed that the genetic algorithm is suitable for machining fixture layout optimization. This paper shows that genetic algorithm can be used for optimization of fixture layout and design. Li (2001), investigated the effect of workpiece dynamics under optimal fixture design. This work shows that the basic 3-2-1 principle was not only the design to give better fixture. The clamping force with the smallest magnitude has maximum relative error. According to this paper it was reported that the solution obtained is irrelevant to the selected initial condition. Krishnakumar Kulankara (2002), it was shown that the reduction in workpiece form error induced by elastic deformation during clamping and machining has been considerably larger with the iterative procedure than with the layout or clamping force optimization alone. Future efforts would focus on extending this technique to incorporate fixture element elasticity and dynamic effects. Neemettin Kaya (2005), proposed a way for the machining fixture location and clamping position using genetic algorithms. Weifang Chen (2007), found out the way to minimize the deformation by changing the clamping force and layout dimension. The results of this study show that the objective with multi dimension method of optimization is more effective in minimizing the deformation. Yu Zheng (2010), reports about the usage of geometric approach to automated design of fixture. In this method very large number of candidates are executed easily. The various initial conditions are used to choose the result possessed. Selva Kumar (2012), describes the way of optimizing the fixture layout using mathematical approach. Based on the equilibrium of forces and moment condition the overall deformation of the fixture is minimized. The optimum clamping forces for the corresponding layout with minimum forces which are required to hold the work without slip. Selva Kumar (2013), found a way to optimize the layout by using GA and artificial neural network. In this paper genetic algorithm has been used. And also the combination of GA and Artificial neural network was used for the optimization of fixture layout design.

2. METHODOLOGY

- Changing clamping force in fixture layout
- Finite element Analysis
- formulation of objective function and Boundary conditions

- Optimization
- Experiment

Analysing the Change of Clamping Force: The layout dimension is kept constant and the clamping force is changed according to friction law of coloumb. The coulomb law of friction is used to change the clamping force. The table.1, shows the layout dimension. The parameter of simulation is given in the table.2.

Table.1. Layout dimension

S.No	ZL1	ZL2	XL3	XL4	XL5	XL6	XC1	ZC2	ZC3
1	114.4	50.4	110.6	119.1	119.1	50.9	110.6	110.6	74.8

Table.2. Simulation parameters

S.No	**Simulation parameters**	
1	Diameter of cutter	25.5 mm
2	Number of flutes used	4
3	Speed of the spindle	661 rpm
4	Feed rate	0.2052 mm/tooth
5	Radial depth	25.5 mm
6	Axial depth	3.91 mm
7	Helix angle	46^o
8	Rake angle	10^o
9	Length of projection	92.18 mm
10	Force for machining	F_x=1105.67, F_z=283.56 N, F_Y=442.10
11	Workpiece dimension	127mm*127mm*38.1mm

Deformation on Changing the Clamping Force (FEA): The clamping force is changed for the above optimized layout by using coulomb law of friction. The clamping force is changed and it is analyzed to get the deformation results which is shown in the table.3. The figures.1, 2, 3, 4 are results obtained from Ansys software for the corresponding clamping forces.

Table.3. clamping forces

S.No	**C1 in (N)**	**C2 in (N)**	**C3 in (N)**	**Total deformation in (mm)**
1	550	400	165	0.047522
2	1000	341.1	152	0.074428
3	738.5	341.1	211	0.075724
4	850	341.1	185	0.046269
5	738.5	450	203	0.076858

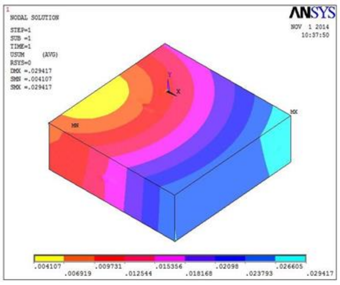

Figure.1. Result 1

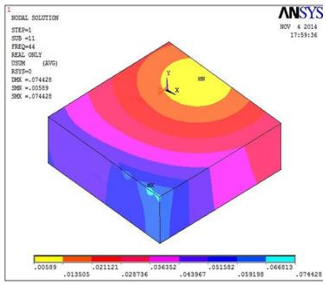

Figure.2. Result 2

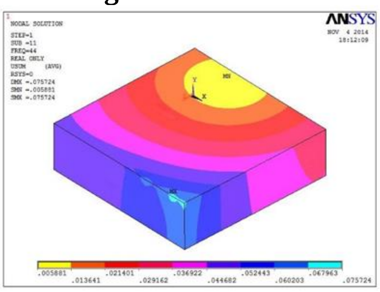

Figure.3. Result 3

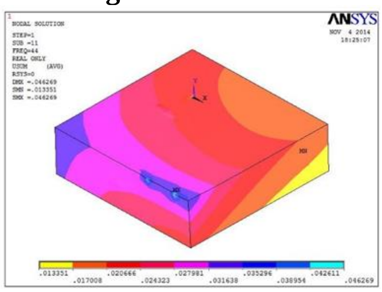

Figure.4. Result 4

These ANSYS result shows the total deformation of the workpiece for the optimized clamping forces obtained from the shuffled frog algorithm.

Clamping Force Optimization: Steps involved in shuffled frog leaping algorithm
Initialize
Generate virtual population
Rank frogs
Partition frogs in to memeplexes
Memetic evolution within each memeplex
Shuffle memeplexes
Check convergence
Boundary Condition for The Clamping Forces: In shuffled frog leaping algorithm the clamping forces are optimized and the moment value is calculated. According to the stick slip condition the range of clamping force are given in the optimization problem.

Table.4. Clamping force limits

Clamping force	Range (N)
C1	400-1600
C2	95-411
C3	3-186

Position of the locators and clamps in the layout: The position of the locators and clamps are kept constant while calculating the moment value.

Table.5. Position of the locator and clamps in the layout

S.No	ZL1	ZL2	XL3	XL4	XL5	XL6	XC1	ZC2	ZC3
1	114.4	50.4	110.6	119.1	119.1	50.9	110.6	110.6	74.8

Objective Function:

- P = Npar

It gives the dimension of the search space.

- N = 20

The number of frog population pairs.

- Mem. No = 8

It denotes the number of memeplexes.

- B = 5

B gives the ratio between Evolution coefficient and leap length.

- G = 10

It denotes the number of generations.

Result Obtained From the Optimization: The result is based on the minimum moment value for optimized clamping force. The main function of this optimization programme is to give the minimum moment value. Based on the criteria the programme shuffled the three clamping force value and substitute it on the moment calculating equation to get the minimum moment values. As a result the clamping force which gives the minimum moment values considered to be the fittest one.

Table.6. Optimized clamping force

Clamping force	**Clamping force**	**Clamping force**	**Moment**
C1(N)	C2 (N)	C3(N)	(N-mm)
440	341	135	159
437.75	340.78	134.64	166
434.95	340.01	133.25	154
410	340	130	168
414.56	341.75	130.85	147
417	342.35	131.76	201
418.75	342.45	133.85	179
425	323.26	133.96	142
427	323.75	135	311
738.5	341	85	119
755	341.25	149	398
755.7	410..8	56	384
812	410	112	377
888	322.4	55.7	412
904.4	409	68.1	611
922	350.4	74.2	588

633	283	80.3	122
679	283.95	83.9	512
667.25	289.65	36.5	456
745	288	45	253
7445.26	289	139	755
1200	521	122	889
1185	525	235	799
942	392	104	852

The optimized clamping forces are randomly selected and displayed along with its moment value. These clamping forces are applied in the dynamic analysis to calculate the corresponding total deformation in end milling operation of prismatic workpiece. The table.7, shows the optimized values of clamping forces for the corresponding design. The figures.5 ,6, 7, 8 shows the ansys results for the respective clamping forces.

Total deformation values for the optimized clamping forces:

Table.7. ANSYS result for optimized clamping force

ANSYS result which show the total deformation for corresponding clamping forces				
S.No	**C1 (N)**	**C2 (N)**	**C3 (N)**	**Total deformation (mm)**
1	425	323.26	133.96	0.046361
2	418.75	342.45	133.85	0.047517
3	410	340	130	0.047328
4	414.5	341.75	130.85	0.047423
5	417	342.3	131.7	0.047378

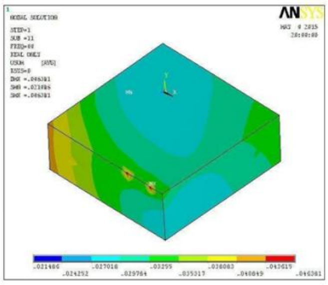

Figure.5. Optimized Result 1

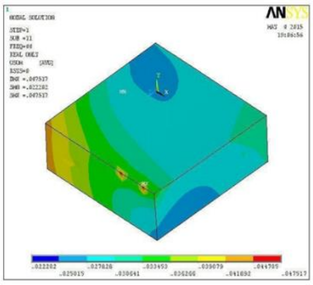

Figure.6. Optimized Result 2

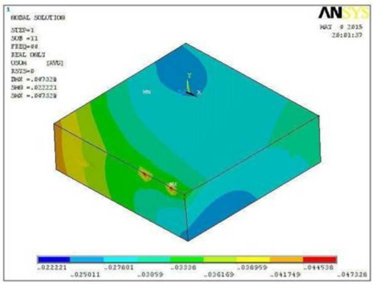

Figure.7. Optimized Result 3

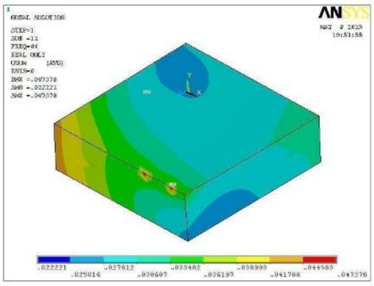

Figure.8. Optimized Result 4

The above table.7, tabulates the total deformation value for the corresponding clamping force values.

3. RESULTS AND DISCUSSION

It shows the ANSYS results for the corresponding clamping forces shown in table

Best Optimum Solution Obtained From ANSYS: The minimum total deformation is achieved for the prismatic work made of aluminium 6061 during end milling process is 0.036961mm.The usage of shuffled frog leaping algorithm technique has given a better result than the mathematical approach (0.059829mm).The dynamic analysis is carried down for clamping forces generated by the shuffled frog algorithm. Among the optimized clamping forces, the one which gives the minimum total deformation value is considered to be the fittest clamping force value.

Table.8. Best optimum solution

S.No	**C1 N**	**C2 N**	**C3 N**	**Total deformation mm**
1	440	341	135	0.036961

This work can be further carried out by experimental justification of the above optimized solution.

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