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Experimental Stress Analysis In A Fixture System Using, Fea

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Abstract
Knowledge of stress induced by loading in a fixture–work piece system is important to ensure quality part production. Suitable methods for accurately predicting such stress are essential to the design and operation of fixtures. In this regard, finite element modeling has been widely applied by researchers and practitioners. However, these studies generally neglect the role of compliance of the fixture body on experimental stress analysis. Also lacking is knowledge of the effects of different finite element model parameters on work piece deformation. This study uses finite element analysis (FEA) to model a fixture–work piece system and to explore the influence of compliance of the fixture body on work piece deformation. In addition, the effects of certain finite element model parameters on the prediction accuracy are also examined. Experimental verification of the stress and strain predicted by the FEA model shows agreement within 4% of the experimental data. The remainder of deformation occurred in the other fixture components. The accuracy and computational time tradeoffs are given for various fixture models.

Key- word: - 3-2-1 Fixture model, static analysis, experimental set-up, validate result.

1. Introduction
Methods for analyzing fixtures are essential to the practice and economics of machining. In particular, the ability to model and stress by fixturing loads and/or predict the unknown fixture–workpiece contact forces are crucial for designing functional fixtures. The most common modeling and analysis approaches used for fixture–workpiece systems include the rigid body approach; the contact mechanics based approach and the finite element modeling approach. Of these approaches, the rigid body modeling approach is by definition incapable of predicting workpiece deformations and is therefore unsuitable for analysis of the impact of fixturing on part quality. The contact mechanics approach, although attractive from a standpoint of computational effort, is limited to parts that can be approximated as elastic half-spaces. Models derived from this approach are capable of stress analysis However; they are not applicable for thin, compliant parts. Finite element models on the other hand are very powerful and are capable of accounting for all nonlinearities present in the system.

Although use of finite element models has been widely reported in the literature and employed in practice, a clear understanding of the role of the different fixture accuracy of workpiece deformation is lacking. Also knowledge of the effects of different finite element model parameters on workpiece deformation is lacking. A common assumption in application of Finite Element Analysis (FEA) to analyze a fixture–workpiece system is that

The fixture is completely rigid since it is much stiffer than the workpiece in many applications. In most such cases, the workpiece is modeled and nodes at the location of fixture contact are completely restrained. This formulation is commonly referred to as a single-point contact. Omitting fixture elements does not allow for the model to account for compliance in the fixture and neglects frictional contact effects between the fixture and workpiece. Other researchers [13] have utilized linear springs to approximate the stiffness of the fixture components. However, such an approach requires the stiffness to be measured or approximated, adding time and introducing potential error into the analysis. Recent work [17–19] has explored the use of surface-to-surface contact elements.

Such an approach allows frictional effects to be modeled. This methodology was used for the work reported in this paper. Liao et al. [17] used FEA with contact elements to model a multiple-contact fixture system. They, however, did not investigate the effects of friction and meshing parameters on the results. Satyanarayana's [18, 19] work was limited to a single fixture–workpiece contact. More importantly, these studies did not analyze the contribution of fixture body compliance to the overall deformation. This paper investigates the effects of various finite element modeling parameters, such as stress, strain. In addition to modeling the workpiece and such as support blocks, base plate, etc. on workpiece deformation is also examined. The FEA predictions of work piece of stress and strain are experimentally verified.

Nomenclature:-

ε	Strain (mm/mm)	σ	Stress (Mpa)
E	Elastic modulus (Mpa)	ν	Poisson's ratio

C11,C12, C13,C21,C22,C23=Different clamping force (N)
L1, L2, L3, L4, L5, L6= Different no. of locator.

2. Fixture–work piece system:-
The fixture–work piece system used in this study consisted of a hollow block of rectangular section and uniform wall thickness restrained in a 3-2-1 fixture layout as shown in Fig.1 The M.S. steel (E=210GPa, ν= 0.334) work piece measured

Length=155 mm width=125, mm, height=65 mm and had a fixed wall thickness (t =4mm) Fig. 1 Two clamps were used to press the work piece against six locators: three on the primary plane, two on the secondary plane, and one on the tertiary plane. Mead of steel (E=206 GPa, ν=0.28) fixture tips with black oxide finish were used to locate and clamp the work piece.

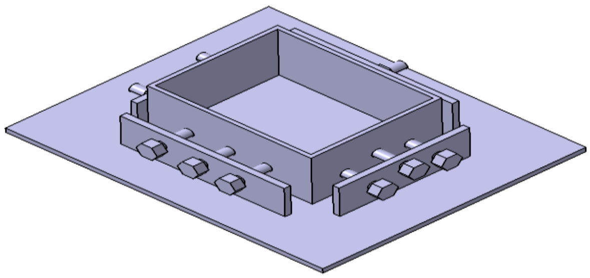

Figure 1: 3-2-1 Fixture system

Figure 2: 2-D drawing detail dimension

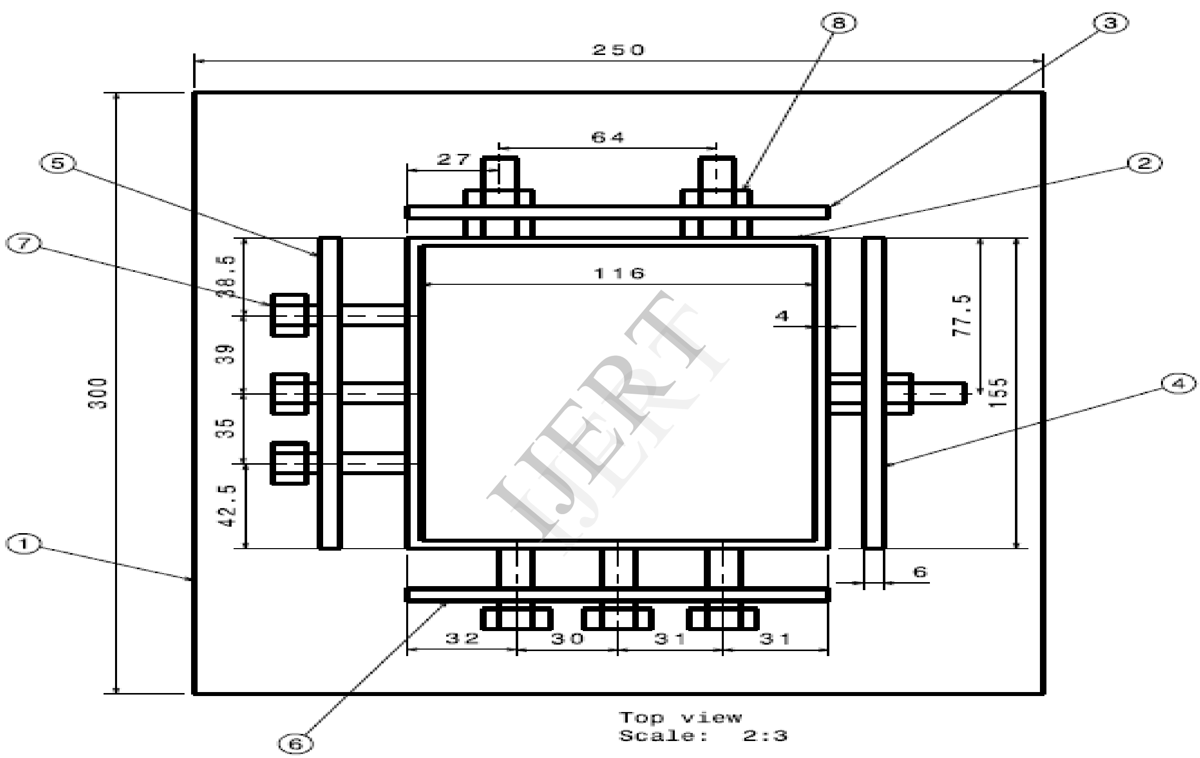

Table1: Part list of fixture model

Sr.No.	Part name	Quantity	Material
1	Base plat	1	M.S.
2	Main body	1	M.S.
3	Support	4	M.S.
5	Clamping-1	3	M.S.
6	Clamping-2	3	M.S.
7	Nut	6	M.S.
8	Bolt	12	M.S.

3) Static Analysis.

Different force applies on work piece, following result bellow:-

Geometry & Material property

Material property:-

Young modulus (E) =106GPa.

Poisson's ratio (ν) : 0.3 - 0.28
Number of element =1956
Number of node =45524

The work piece model is mesh with triangular element. 10N to 240N Force Appling on deferent location, then to prediction of which location is maximum deformation. Same magnitude of force apply at C11, C12, C13, C21, C22 and C23.shows are gives following results,

Table 2: FEA strain results

FEA- Strain						
Force	Case-1(C11)	Case-2(C12)	Case-3(C13)	Case-4(C21)	Case-5(C22)	Case-6(C23)
10	1.653E-05	8.511E-06	1.57E-05	1.14E-05	7.96E-06	1.12E-05
20	3.07E-05	1.70E-05	3.15E-05	2.28E-05	1.59E-05	2.24E-05
30	4.479E-05	2.553E-05	4.72E-05	3.42E-05	2.39E-05	3.35E-05
40	5.89E-05	3.40E-05	6.30E-05	4.56E-05	3.18E-05	4.47E-05
50	7.305E-05	4.256E-05	7.87E-05	5.70E-05	3.98E-05	5.59E-05
60	8.72E-05	5.11E-05	9.45E-05	6.83E-05	4.77E-05	6.71E-05
70	0.0001013	5.958E-05	1.10E-04	7.97E-05	5.57E-05	7.83E-05
80	1.15E-04	6.81E-05	1.26E-04	9.11E-05	6.36E-05	8.94E-05
90	0.0001296	7.66E-05	1.42E-04	1.03E-04	7.16E-05	1.01E-04
100	0.0001589	0.000082	1.51E-04	1.09E-04	7.62E-05	1.05E-04
125	2.07E-04	1.06E-04	1.97E-04	1.42E-04	9.94E-05	1.40E-04
150	0.0002544	0.0001308	2.42E-04	1.76E-04	1.23E-04	1.75E-04
175	3.02E-04	1.55E-04	2.88E-04	2.09E-04	1.46E-04	2.10E-04
200	0.0003499	0.0001796	3.33E-04	2.43E-04	1.69E-04	2.45E-04

Calculate reaction force at different location, L1, L2, L3, L4, L5, and L6.

Table3: FEA stress results

Stress(Mpa)						
Force	Case 1(C11)	Case2(C12)	Case3(C13)	Case4(C21)	Case5(C22)	Case6(C23)
10	3.4719	1.7874	3.3062	2.919	1.6707	2.3479
20	6.9438	3.5748	6.6123	4.7838	3.413	4.6958
30	10.4157	5.3622	9.9184	6.6486	5.1553	7.0437
40	13.8876	7.1496	13.2245	8.5134	6.8976	9.3916
50	17.3595	8.937	16.5306	10.3782	8.6399	11.7395
60	20.8314	10.7244	19.8367	12.243	10.3822	14.0874
70	24.3033	12.5118	23.1428	14.1078	12.1245	16.4353
80	27.7752	14.2992	26.4489	15.9726	13.8668	18.7832
90	31.2471	16.0866	29.755	17.8374	15.6091	21.1311
100	33.382	17.376	31.9878	22.863	15.993	21.976
125	43.399	22.342	41.327	29.899	20.883	29.349
150	53.416	27.308	50.6662	36.935	25.773	36.722
175	63.433	32.274	60.0054	43.971	30.663	44.095
200	73.45	37.24	69.3446	51.007	35.553	51.468

3.1 Balancing force-moment method:

Equilibrium occurs when the sum of all forces in the x, y and z direction is zero and the sum of moments at any point is zero.

$$F = 0, M = 0$$

Coulomb friction law: To verify the calculated clamping forces are enough to hold the work piece, the forces in the each direction are multiplied by the static friction coefficient value. This will give the friction force values due to the clamps and locators. For equilibrium condition, the amount of friction force should be greater than or equal to the machining force. Tool is at initial Position (101.6 mm, 0, 127 mm) R1 to R6 are reactions at L1 to L6.

∑ML1=0
{(C1*53.1)+(C2*0)+(C3*50.8)+(R1*114.5)+(R2*12.7)+

(R4*12.7)+(R5*114.3)+
(R6*63.5)+(Fx*127)+(Fy*127)+(Fz*38.1)} =0

∑ML2=0

{(C1*40.6)+(C2*63.5)+(C3*50.8)+(R2*101.6)+(R3*63.5)+(R4*114.3)+(R5*114.5)+(R6*12.7)+(Fx*114 .1)+(Fy*101.3)}=0

∑ML3=0

{(C1*53.1)+(C2*0)+(C3*50.8)+(R1*114.5)+(R2*12.7)+

(R4*12.7)+(R5*114.3)+
(R6*63.5)+(Fx*127)+(Fy*127)+(Fz*38.1)}==0

∑ML4=0

{(C1*53.1)+(C2*0)+(C3*50.8)+(R1*114.5)+(R2*12.7)+

(R4*12.7)+(R5*114.3)+
(R6*63.5)+(Fx*127)+(Fy*127)+(Fz*38.1)}=0

∑ML5=0

{(C1*53.1)+(C2*0)+(C3*50.8)+(R1*114.5)+(R2*12.7)+

(R4*12.7)+(R5*114.3)+
(R6*63.5)+(Fx*127)+(Fy*127)+(Fz*38.1)}=0

∑ML6=0

{C1*53.1)+(C2*0)+(C3*50.8)+(R1*114.5)+(R2*12.7)+(R4*12.7)+(R5*114.3)+ (R6*63.5)+(Fx*127)+(Fy*127)+(Fz*38.1)}=0

MAT Lab software was used to solve the above equations. The required Clamping forces are,

C1 =704.26 N C2 =353.42 N C3 =321.78 N

Like the above when tool is at (101.6 mm, 0, 101.6 mm) the required Clamping forces are,
C1 =678.7 N C2 =48.6 N C3 =1324.9 N
When tool is at (101.6 mm, 0, 76.2 mm) the required Clamping forces are,
C1 =742.4 N C2 =465.2 N C3 =2436.13 N
When tool is at (101.6 mm, 0, 50.8 mm) the required Clamping forces are,
C1 =1002.6 N C2 =548.0 N C3 =1906.6 N
When tool is at (101.6 mm, 0, 25.4 mm) the required Clamping forces are,
C1 = 874.3 N C2 =266.6 N C3 =1537.2 N
The maximum clamping forces among these values are,
C1=1002.6 N C2=548.0 N C3 =2436.1 N
The reaction forces at each locator for these clamping forces are,
R1 = 455.9 N R2 =103.6 N R3 =831.56 N
R4 =1484.6 N R5 =2057.2 N R6 =1370.7 N

3.2 Verification of the calculated clamping forces:

To verify the calculated clamping forces are enough to hold the work piece, the forces in the each direction are multiplied by the static friction coefficient value. This will give the friction force values due to the clamps and locators. For equilibrium condition, the amount of friction force should be greater than or equal to the machining force in that direction.
In the X-direction,
[(C1+C3+R3+R4+R5+R6)*0.25] > Fx
8728.16*0.25=2182.04 > 1105

In the Y-direction,
[(C1+C3+R1+R2+R4+R5+R6)*0.25] > Fy
8910.02*0.25=222705 > 4421
In the Z-direction,
[(C1+C2+R1+R3)*0.25] > Fz.
2941.66*0.25=735.415 > 283.56
Thus, the calculated clamping forces are verified by the coulomb friction law. Finite element model of the work piece fixture system FEM software ANSYS was used to fine the deformation of the work piece.

3.3 Graphical representation of FEA results:-

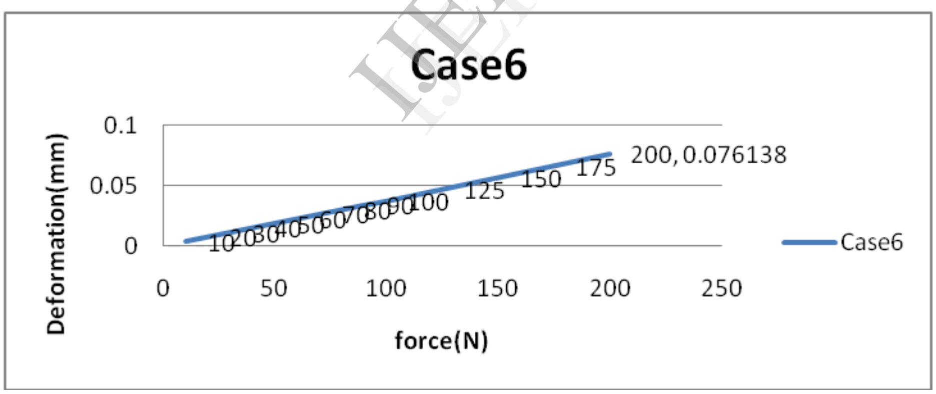

Figure 3: Deformation v/s force

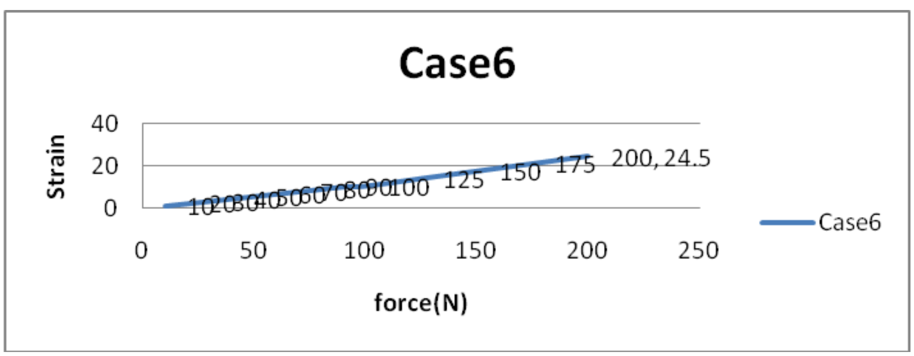

Figure 4: strain v/s force for

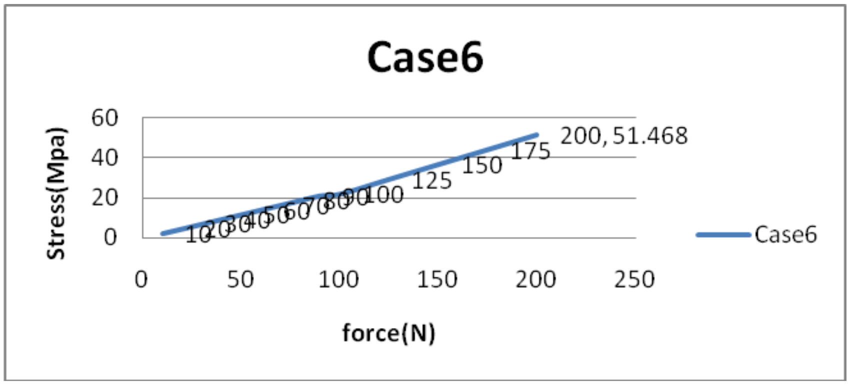

Figure 5: Stress v/s force

When force 100N applies clamping forces required to hold the work piece with minimum work piece deformation. The clamping force position at C23 is optimal. At position stress and strain is constant and also work piece deformation.

4) Experimental validation

4.1) Experimental Set-Up:-

Procedure for experiment: As shown fig.-6, strain gauge mounted on inside the wall of hollow work piece. The two terminal of strain gauge is connected with strain gauge indicator. The strain gauge indicator gives direct values of strain. Load cell mounted in between clamping force and work piece. Clamping force applying on work piece through load cell.

The adjusted magnitude of clamping with help of load cell and measure the corresponding Strain. The magnitude of clamping force measure with load cell, and measure corresponds strain value s shown on strain gauge indicator. Calculated stress using relation E= ε σ. where E=210Gpa. Different magnitude of clamping force applies on work piece through load cell, measure corresponding strain. Same procedure applies on various cases shown following tabule-4, 5, results.

Figure 6 Experimental set-up

Experimental reading:-

Table4: measured strain values

Measured strain					
C11	C12	C13	C21	C22	C23
1.8	0.9	1.873	1.1703	0.999	2.122
3.75	1.90735	4.1523	3.293	2.932	4.242
6.002	3.753	6.734	3.343	3.3932	5.35
7.89	5.0405	8.3023	6.5632	5.18	6.472
9.305	6.256	9.872	7.705	5.98	7.593
10.02	7.11	11.452	8.833	6.775	8.711
13.02	7.95	13.023	9.238	7.573	9.832
14.02	8.81	14.604	11.231	8.365	11.023
14.02	9.66	16.4204	12.035	9.1623	12.04
17.89	10.82	17.104	13.09	9.622	12.05
21.92	11.06	20.704	17.42	11.943	16.042
26.44	15.08	26.426	20.76	14.322	19.504
31.02	17.57	30.88	23.09	16.46	23.045
36.05	20.98	35.33	27.032	18.092	26.45

Table 5: measured stress values

Measured stress (Mpa)					
C11	C12	C13	C21	C22	C23
3.78	1.89	3.9333	2.45763	2.0979	4.4562
7.875	4.005435	8.71983	6.9153	6.1572	8.9082
12.6042	7.8813	14.1414	7.0203	7.12572	11.235
16.569	10.58505	17.43483	13.78272	10.878	13.5912
19.5405	13.1376	20.7312	16.1805	12.558	15.9453
21.042	14.931	24.0492	18.5493	14.2275	18.2931
27.342	16.695	27.3483	19.3998	15.9033	20.6472
29.442	18.501	30.6684	23.5851	17.5665	23.1483
29.442	20.286	34.48284	25.2735	19.2408	25.284
37.569	22.722	35.9184	27.489	20.2062	25.305
46.032	23.226	43.4784	36.582	25.0803	33.6882
55.524	31.668	55.4946	43.596	30.0762	40.9584
65.142	36.897	64.848	48.489	34.566	48.3945
75.705	44.058	74.193	56.7672	37.9932	55.545

4.2) Validation of the Results:-

The general validate of finite element method obtained above stress analysis of work piece system in deferment forces. An identical experimental set-up was used as in section-4. The different magnitude of force applies on work-piece. Following table presents the corresponding experimental and FEA results. As table shows, there are lees then 4% error between the FEA and experimental values.

Table 6: Predicted vs. measured strain for clamping position at C11,

FEA strain	1.653	3.07	4.479	5.809	7.309	8.72	10.13	11.5	12.96
Measured	1.8	3.75	6.002	7.89	9.305	10.02	13.02	14.02	14.02
Error (%)	-0.147	-0.68	-1.523	-2	-2	-1.3	-2.89	-1.06	-2

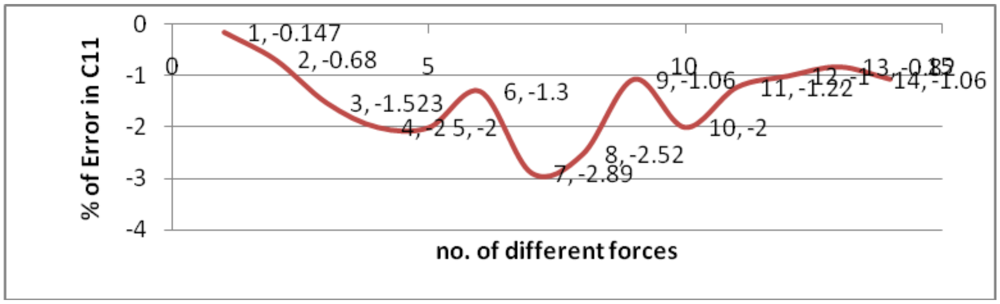

Figure 7: % of error in clamp C11.

Table 7: Predicted vs. measured strain for clamping position at C12,

FEA strain	0.08521	1.70	2.553	3.40	4.256	5.11	6.81	7.66	8.2
Measured	0.9	1.9075	3.753	5.040	6.256	7.11	7.95	8.81	9.66
Error (%)	-0.814	-0.2074	-1.2	-1.645	-2	-2	-1.992	-2	-2

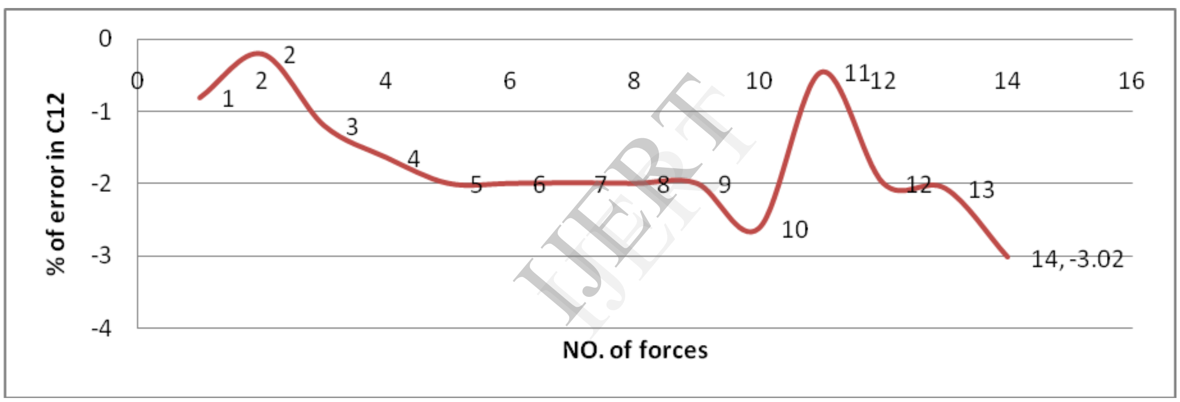

Figure 8: % of error in clamp C12

Table8: Predicted vs. measured stress for Clamping position at C23

FEA stress Mpa	1.12	2.24	3.35	4.47	5.59	6.71	7.83	8.94	10.10
Measured	2.122	4.242	5.35	6.472	7.593	8.711	9.832	11.023	12.04
Error (%)	-1.002	-2.002	-2	-2.002	-2.002	-2.003	-2.001	-2.02	-1.34

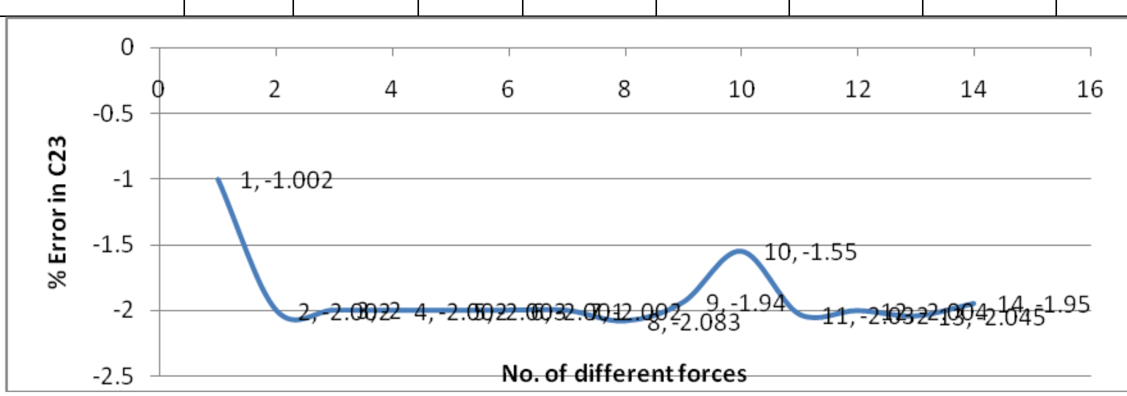

Figure9: % of error in clamp C23

5. Summaries:

- To calculate the minimum clamping forces required to hold the work piece, the friction forces due to locators and clamps are considered.
- The balancing force-moment equations are also used here to calculate the clamping forces and the reaction forces due to the locators.
- Although, the finite-element method is best suited for predicting an elastic deformation of the work piece and reaction forces, it has been mainly used for determining the elastic deformation at work piece-fixture contact points.
- Most of the studies do not consider the dynamic machining forces in the fixture optimization design to minimize the dynamic response of the work piece.
- Most researchers did not consider the material removal effect in the analysis.

6. Conclusion: ·

- 4% of Error exists in between Experimental and theoretical calculated.
- The maximum deformation of work piece is depends on location of clamping force.
- There is a Deviation of results between Experimental and FEA of 4% for stress and 2% for strain.
- To calculate the minimum clamping forces required to hold the work piece, the friction forces due to locators and clamps are not considered.
- The balancing force-moment equations are also used here to calculate the clamping forces and the reaction forces due to the locators.
- Although, the finite-element method is best suited for predicting an elastic deformation of the work piece and reaction forces, it has been mainly used for determining the elastic deformation at work piece-fixture contact points.
- Most of the studies do not consider the dynamic machining forces in the fixture optimization design to minimize the dynamic response of the work piece.

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