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INVESTIGATION OF STRESSES IN CANTILEVER BEAM BY FEM AND ITS EXPERIMENTAL VERIFICATION

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Abstract - The main objective of this study is to verification of stresses developed in cantilever beam. The maximum stress is induced in the cantilever beam is at support and failure of beam takes place at support .Hence in this work evaluation of stresses in cantilever beam over a span is studied using finite element method and strain gauge technique. The stress and deflection analysis at different section is carried out. The result of finite element method is verified with experimental and analytical solution.

Keywords: Cantilever plate; FEM; Strain gauge; Static loading.

I. INTRODUCTION

While analysis of stresses in cantilever beam we are using three technique i.e. analytical analysis, FEM analysis and experimental analysis.

The mild steel flat plate having cross section 25×5 mm and 395mm in length used as a beam. This beam is fixed at one end and load is applied at other end. In analytical analysis load of 1.256kg (load with pan load) is applied at the end of beam and stresses at a distance of 15mm, 115mm,215mm, 315mm from support is calculated with the help of empirical relation and also calculate the tip deflection with different load range.

In experimental technique, load is applied at the end of beam having 1.256 kg (load with pan load) the strain gauges are located at a distance of 15mm, 115mm , 215mm, & 315mm from the support. We are observing o/p voltage in strain gauges and see the effect of stress and strain at a required position of strain gauge over a cantilever beam at different load.

In FEM technique using ANSYS 11 software again similar load is applied on cantilever beam and observe the effect of loading at a distance of 15mm , 115mm , 215mm and 315mm from fixed end for the load ranges from 1.256 to 5.256 kg at a difference of 1kg.

II. METHODOLOGIES

A. Experimental analysis

In experimental analysis, actual prototype is considered under static load. A metal foil gauge having resistance 120Ω and gauge factor 2.0 is used for the strain measurement. The instrumentation is developed for this work the instrumentation measure only change in resistance i.e. Δ R. This change in resistance in mili volts is converting into voltage with the help of Wheatstone bridge circuit and digital multimeter. The four strain gauge are located on a cantilever plate. The strain gauge no. 1, 2, 3 & 4 are located at a distance of 15mm, 115mm, 215mm, & 315mm respectively from the fixed support. The one end of the plate is fixed and load pan is clamped with help of J bolt at other end. The experimental set up as shown in fig 1. Due to application of load resistance of strain gauge wire changes which is measured with help of digital multimeter. This change in voltage is directly proportional to applied strain. The Experimental strain is carried out by equation 1

$dV_o = \frac{1}{4} \times V_s \times F \times \varepsilon$ (1)

where

Vs	=	Supply voltage in volts
dVo	=	Change in voltage in mill volts
F	=	Gauge factor=2
Ε	=	Experimental strain

Experimental stress is given by equation 2

$\sigma b = \varepsilon x E$ (2)

E=Young modulus of material of material

The one by one strain gauges is connected to Wheatstone bridge circuit and the load is added in the step of 1 to 5 kg.

A pen plotter system is provided at the free end of plate to measure the deflection at the tip. The deflection is measured on a Cart board with scale which is shown in fig no.2. All the experimental results are tabulated in table no.1.

Fig. 1 Experimental Setup for measurement of stress

Fig. 2 Experimental Setup for measurement of deflection

Table 1. Comparison of Experimental Stresses and tip deflection at different load over span

SR.NO.	TOTAL LOAD(KG)	TOTAL LOAD(N)	EXPERIMENTAL STRESS IN (N/mm²)				EXPT.DEFLECTION IN(MM)
			STRAIN GAUGE NO.1	STRAIN GAUGE NO.2	STRAIN GAUGE NO.3	STRAIN GAUGE NO 4	
1	1.256	12.321	41.1	24.09	20.65	13.77	13
2	2.256	22.131	51.63	48.19	44.75	27.53	16
3	3.256	31.941	130.81	65.40	65.31	29.1	20
4	4.256	41.751	154.91	117.04	61.95	34.56	24
5	5.256	51.561	182.45	151.47	75.63	39.8	28

B. Finite element analysis

The model of cantilever beam having dimensions 25×5 mm cross-section and length of 395mm. The model is developed by using ANSYS software. After the generation of model, 10 node solid92 tetrahedral element is used for analysis. The properties of material such as $E=2.1\times10^5$ N/mm^2 and position's ratio=0.28 are provided and mesh model is developed. The constrained are provided on one end of cantilever beam on a area with all degree of freedom. The load is applied on other end on top side of node in Y-direction. After solving, the first principle stress counter at nodal region for the load ranges from 1.256kg to 5kg in the steps of 1kg as shown in fig no.3,4.,5,6&,7respectively.

The FEM stresses at each load at a distance of 15mm, 115mm,215mm, 315mm and tip deflection at each load are tabulated in table no.2

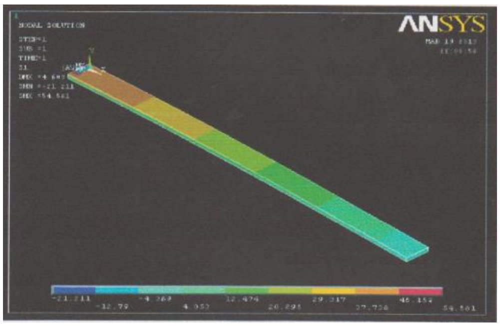

Fig.3 First principle stress counter for1.256kg

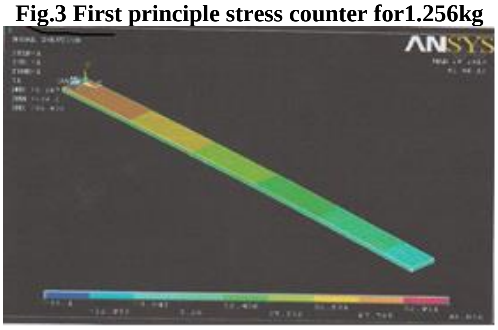

Fig.4 First principle stress counter for 2.256kg

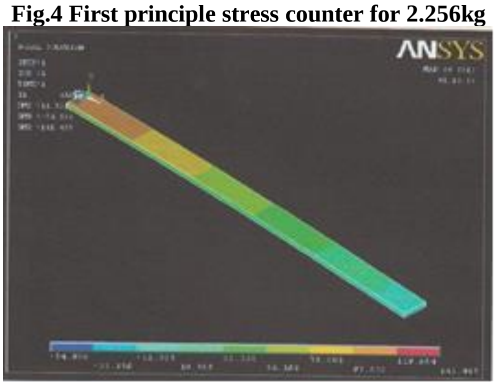

Fig. 5 First principle stress counter for 3.256kg

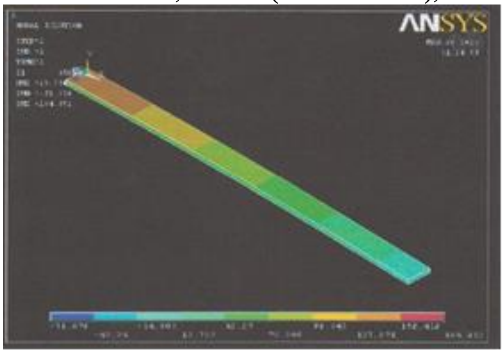

Fig.6 First principle stress counter for 4.256kg

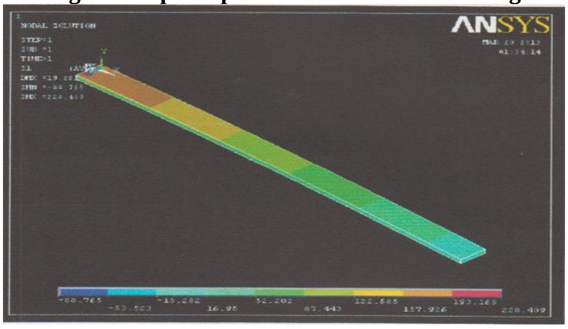

Fig. 7 First principle stress counter for 5.256 kg.

Table 2. . Comparison of FEM Stresses and tip deflection at different load over span

SR. NO.	TOTAL LOAD(KG)	TOTAL LOAD(N)	FEM STRESS IN (N/mm²)				FEM.DEFLECTION IN(MM)
			AT 15mm FROM FIXED END	AT 115mm FROM FIXED END	AT 215mm FROM FIXED END	AT 315mm FROM FIXED END 4	
1	1.256	12.321	44.25	32.82	21.00	9.81	4.60
2	2.256	22.131	79.48	58.95	37.73	16.49	8.267
3	3.256	31.941	114.95	85.09	54.46	23.80	11.92
4	4.256	41.751	149.92	111.22	71.9	31.11	15.59
5	5.256	51.561	185.18	137.36	87.91	38.42	19.26

C. Analytical Analysis

For the analytical analysis the following specification are considered

Load applied=P

Weight of pan with J bolt= 256gm=0.256kg.

Total weight including applied load with wt. Of pan &clamp= W

Span from load end to strain gauge No.1 L_1=380mm

Span from load end to strain gauge No.1 L_2=280mm

Span from load end to strain gauge No.1 L_3=180mm

Span from load end to strain gauge No.1 L_4=80mm

Width of Plate b=25mm

Thickness of plate t=5mm

Analytical stress is calculated by

$$\sigma b = 6\,WL / bt^2 \quad (3)$$

The stresses at each strain gauge location is calculated by using above equation by changing the value of L.as L_1, L_2, L_3, L_4 respectively for the application of load 1kg,2kg, 3kg, 4kg &5kg respectively.

Analytical deflection at tip of cantilever plate is given by

$$\delta = (W \times L^3) / (3 \times E \times I) \quad (4)$$

Modulus of elasticity

$E = 2.1\text{X}10^5$ N/mm^2

Span of beam L=395mm

M.I. of plate =I

$$I=(b\times t^3)/12 \quad (5)$$

The analytical stress at each strain gauge location at adifferent load and tip deflection at different load are tabulated in table no.3

Table 3. . Comparison of Analytical Stresses and tip deflection at different load over span

SR. NO.	TOTAL LOAD (KG)	TOTAL LOAD (N)	ANALYTICAL STRESS IN (N/mm^2)				ANALYTICAL .DEFLECTION IN(MM)
			AT 15mm FROM FIXED END	AT 115mm FROM FIXED END	AT 215mm FROM FIXED END	AT 315mm FROM FIXED END	
1	1.256	12.321	44.94	33.11	21.29	9.46	4.60
2	2.256	22.131	88.73	59.48	38.24	16.99	8.31
3	3.256	31.941	116.52	85.85	55.19	24.53	11.99
4	4.256	41.751	152.30	112.22	78.14	32.06	13.68
5	5.256	51.561	188.09	138.59	88.09	39.59	19.36

III. COMPARISON OF RESULTS

For the analysis purpose the FE stresses and deflections on cantilever plate is carried out at a distance of 15mm, 115mm, 215mm & 315mm from the support. The comparative FE, experimental and analytical stress results are tabulated in table no.4 and their respective variation in stresses are shown in fig.no.8, 9, 10&11.The tip deflection at different load is also tabulated in table no.5 and their variation are as shown in fig.no.12.The maximum stress at maximum load with respect to span is also compared which shown in fig no.13.

Table 4. Comparison of FE, Experimental, Analytical Stresses and tip deflection at different load over span

SR. NO.	TOTAL LOAD (N)	STRESSES IN (N/mm^2)											
		AT 15mm FROM FIXED END			AT 115mm FROM FIXED END			AT 215mm FROM FIXED END			AT 315mm FROM FIXED END		
		σE	σF	σA	σE	σF	σA	σE	σF	σA	σE	σF	σA
1	12.321	41.1	44.25	44.94	24.09	32.82	33.11	20.65	21.00	21.29	13.77	9.81	9.46
2	22.131	51.63	79.48	88.73	48.19	58.95	59.48	44.75	37.73	38.24	27.53	16.49	16.99
3	31.941	130.81	114.95	116.52	65.40	85.09	85.85	65.31	54.46	55.19	29.1	23.80	24.53
4	41.751	154.91	149.92	152.30	117.04	111.22	112.22	61.95	71.9	78.14	34.56	31.11	32.06
5	51.561	182.45	185.18	188.09	151.47	137.36	138.59	75.63	87.91	88.09	39.8	38.42	39.59

Table 5. Comparison tip deflection at different load

SR.NO	TOTAL LOAD (N)	ANALYTICAL DEFLECTION (mm)	FEM DEFLECTION (mm)	EXPERIMENTAL DEFLECTION (mm)
1	12.321	4.60	4.60	13
2	22.131	8.31	8.267	16
3	31.941	11.99	11.92	20
4	41.751	13.68	15.59	24
5	51.561	19.36	19.26	28

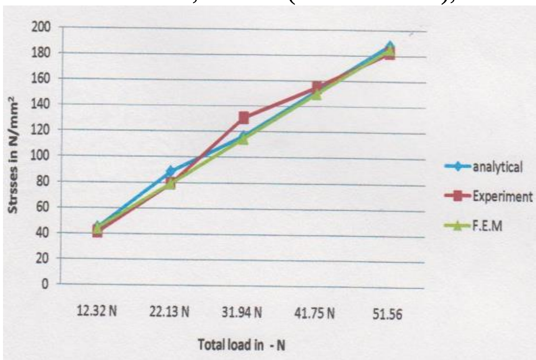

Fig.8. Variation of Stresses at adistance of 15mm from fixed support

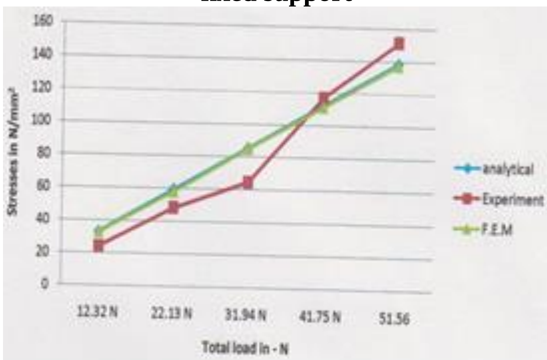

Fig. 9 Variation of Stresses at adistance of 115mm from fixed support

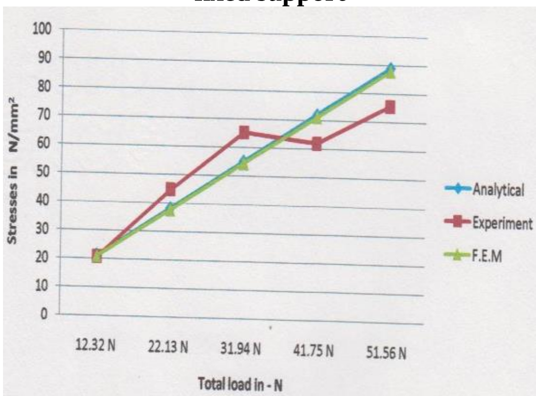

Fig.10 Variation of Stresses at adistance of 215mm from fixed support

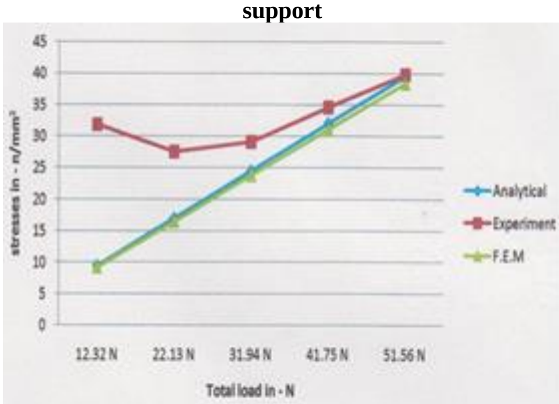

Fig.11Variation of Stresses at adistance of 315mm from fixed

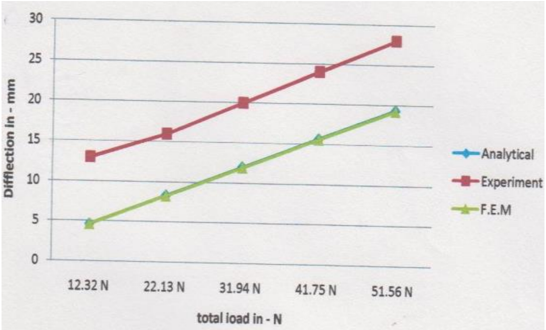

Fig.12. Variation of tip deflection at different load

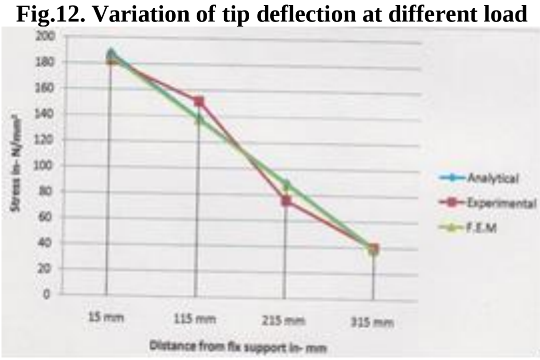

Fig13. Variation of stresses at max. load with respect to span

IV. DISCUSSION AND CONCLUSION

Though the detailed results are presented in earlier, here an attempt is made to compare the results obtained analytically, by FEM and experimentation. For comparison of stresses first principle stress is considered.

A. *Variation of stress and deflection in cantilever plate*

From the Fig. no 8, 9, 10&11 it is observed that FE stresses and analytical stresses is closely matched but in experimental the stress is slightly differ.

The strain gauges at a distance of 15mm and 115mm from fixed support all three analysis are in good agreement with each other, but at a distance of 215mm from fixed support the experimental stress is closely matched at a lower load and when the load increases, it quit differs.

At a distance of 315mm from fixed support the FE and analytical stresses are closely matched, but in experimentation at a lower load the experimental stress highly differs than the analytical and FE stresses. When the load are increasing, all these stresses are closer to each other.

From fig no. 13 it is observed that, at a higher load the nature of the graph of FE, analytical and experimental stresses over a span obtained in the same nature as that of stresses occurred in cantilever beam.

From fig. no.12 it is observed that at the end of the beam, where the load is applied, the analytical and FEM deflection are in good agreement but experimental deflection is quit differ from the above two analysis because of due to inertia and properties of material.

B. *Overall conclusion*

From this study it is conclude that in the analytical and FEM analysis of a beam, observing stresses are nearer to each other, but in experimental analysis as the load increases the experimental stress is nearer to the FE and analytical stresses and also follows the cantilever beam theory. In the deflection concern, the analytical and FE deflection is in good agreement but, the experimental deflection is quite differs from above two analysis because due to inertia effect, material properties and length of beam.

REFERENCES

[1] Gargi Majumdar., (2013) "Deflection and stress analysis of cantilever beam and its validation using ANSYS". Intiernational Journal of Mechanicl engg. ISSN 2249-OO19, Vol. 3. PP. 655 – 662.

[2] Bellagundu; (2002) "Finite element in engineering", 3rd Edition, Prentice Hall India.

[3] Khurmi, R. S.; Gupta, J. K.; (1999) "A textbook of Machine Design" EPH Publication.

[4] Satphy S.M.;(2014)" A project of dynamic analysis of cantilever beam & its experimental validation",Dept.of Mech. Engg.,National institute of Technology,Rourkela.

[5] A.Kursun, M.Tunay Certin; (2014) "Elastic Stress analysis of composite cantilever beam loaded uniformly", Intenational Journal of Mechanical, Aerospace, Industrial and Mechatronics Engineering. Vol;8, No:2.

[6] K.Vijaykumar ;(2014) "Tungsten Cantilever Beam using Ansys, (Model Analysis)", IJES,ISSN 2319-1813 Volume3,P.P .53-59

[7] Tarsicio Belendez; (2003) "Numerical and Experimental Analysis of a Cantilever Beam; a Laboratory project to Introduce Geometric Nonlinearity in Mechanics of Material", Int.J.Engg.Ed, vol.19,No.6,P.P 885-892.