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Estimation of Load acting on a Crane Hook by Inverse Finite Element Method

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***Abstract*— Machines and structures are designed and developed for carrying out certain tasks. Further improvement in quality and performance of the product is possible with design refinement. Finite Element analysis is a technique used for obtaining the stress distribution due to loads applied on the member. The forward finite element analysis is based on some estimated loads. However, the loads actually acting on the machines and structures are unknown. Analysis based on estimated or predicted load has only limited application. The inverse finite element method is a hybrid, experimental and numerical technique for the processing of measurement data taken on existing members which will help us in determining the operating loads.**

In this paper, inverse finite element technique is employed for estimating the load acting on a mechanical member. A fundamental experimental work has been carried out on crane hook. A crane hook having trapezoidal cross-sectional area is used for analysis. The forward FE analysis is carried out in Ansys. The nodal strain at required positions is recorded.

The strain measurements are used in conjunction with the results of finite element analysis to predict the applied load. The magnitude of the load estimated by this method is within 2% of the actual applied load. This demonstrates the advantages of the inverse FEM method for predicting the load.

Keywords : inverse Finite Elemnt, Crane Hook Strain Gauge

I. INTRODUCTION

In engineering, computer-aided design tools are used to design advanced structural systems. Computational simulation techniques are used in such tools to calculate the displacement, deflection, strains, stress; natural frequencies etc for given loading and initial boundary conditions. These types of problems are called forward problems and are governed by ordinary or partial differential equations (ODE or PDE) with unknown field variables. The field variable is basically the displacements.

Another class of practical problems is called inverse problem. In an inverse problem, the effects or outputs displacement, velocity, acceleration, natural frequency, etc. of the system may be known by experiments, but the parameters of the loading profile, material property, geometric feature of the structure, boundary conditions, or a combination of these called inputs may need to be determined.

To solve a forward problem many well established solution procedures are used such as.

- Finite difference method
- Finite element method
- Strip element method
- Boundary element method

The nature of inverse problems requires proper formulations and solution techniques in order to obtain results successfully. The solution techniques are generally called as regularization methods. The different regularization methods such as Tikhonov regularization, singular value decomposition, iterative regularization method, least square method, regularization by filtering etc are used. The following block diagram distinguishes the forward and inverse problem.

II. FORWARD FINITE ELEMENT ANALYSIS

Crane hook, is modeled in Catia v5 , solid45 element is used for meshing of the model in hyper mesh. The meshed modeled crane hook is simulated in ANSYS as a curved beam by fixing at one end and applying distributed load on selected nodes on the beam, strain at different nodes are obtained.

The material and geometrical properties are
Area of cross-section of curved beam, A =1125mm^2,
μ=0.334 ρ=2730e-09 N/mm^3

The one end of crane hook is constrained D.O.F, uniform distributed load is applied at selected nodes at inner surface of crane hook. The measured and simulation readings are compared for optimization.

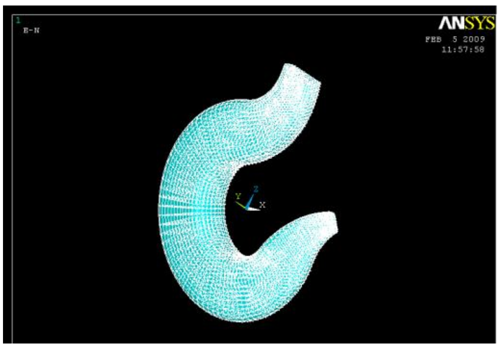

Fig 1 Meshed crane hook

III. EXPERIMENTAL SETUP

An industrial crane hook is taken for experimentation in the laboratory and Strain gauges of $350^{+}5$ ohms are mounted predetermined points within the inner surface of crane hook and a dummy gauge is mounted at the tip of crane hook for temperature compensation. A plunger like fixture is used to load the specimen. The whole set up is fixed to UTM for testing (crane hook and fixture). When the load pulls the plunger ,it pulls the crane hook ,which leads to the tension in the inner fiber of crane hook. These tensions are determined by strain gauges

Fig 2 Experimental setup

The arrangement of loading is done using a fixture as shown .As loads acts on crane hook, the specimen gets strained. The strain is measured using strain gauges mounted at required points.

Fig 3: Strain plot of crane hook

Table 1 Ansys Results

Applied load N	Strain readings(1) Microns	Strain readings(2) microns
100	5.07	11.9
200	10.2	22.66
300	14.5	35.3
400	20	47
500	23	0.58
600	30.6	77.5
700	39.5	86.5
800	40.9	97.1
900	50.8	117
1000	66	137
1100	79.8	162
1200	98.2	191
1300	107	207
1400	112	221
1500	124	239
1600	133	262
1700	140	275
1800	151	294
1900	162	305
2000	175	318

IV. RESULTS AND DISCUSSIONS

The simulation readings are tabulated in the table.1.The known loads are applied on the beam for calibration. A plot of force verses strain is drawn and is shown Method of least square is used to estimate the force on beam.

The strain is measured using strain gauges mounted at required points. The strain reading for different load (Force) is tabulated in table 2.

Table 2 Experimental Results

The readings obtained from forward analysis and the readings measured from experimentation are compared and it is observed that least the difference in experimental and simulation reading cause minimum of functional **π**.

1. **Sensitivity** ensures that effects Y chosen are sufficiently sensitive for the parameters (Pi) and/or the inputs X to be identified.
2. **Accuracy** ensures that the measurement error can be
3. well controlled so that the effects contained are accurate.
4. **Easy to acquire** ensures that the effects can easily obtained experimentally at lower cost and computationally with available efficient forward solver.

$$\prod(\mathbf{x}) = \sum_{i=1}^{ns} \left(y_i^p(x) - y_i^m(x^t) \right)^2$$

Which counts for the sum of the least squares of the errors of predicated outputs based on forward analysis and an assumed X with respect to the measured outputs of the system. n_s is the number of sampling points of the experimental measurement. It is clear that if

X=Xt

Assuming the predication is exact, then

$\prod(x) = 0$

For all other X we have

$\prod(x) \geq 0$

And an X can possibly be found that leads to

$\prod(x)$ --- → minimum.

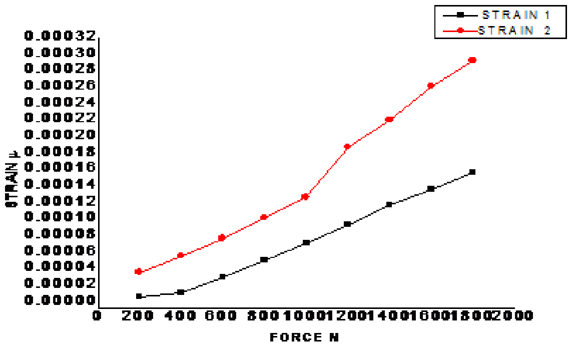

Fig 4 Calibration plot

Table-3 Least Square Method for strain

Applied load N	Strain readings(μ1) Microns	Strain readings(μ2) microns
200	5	34
400	10	54
600	28	75
800	49	100
1000	70	125
1200	92	186
1400	115	218
1600	135	259
1800	155	290

LOAD N	STRAINS (microns)		STRAINS (microns)		MINIMUM ERROR
	$^{A}Y_{P1}$	$^{E}Y_{M1}$	$^{A}Y_{P2}$	$^{E}Y_{M2}$	$\Sigma(^{A}Y_{Pi}-^{E}Y_{Mi})^2$ X10^{-4}
100	5.07	155	11.9	290	9.98
200	10.2	155	22.7	290	9.24
300	14.5	155	35.3	290	8.46
400	20.0	155	47.6	290	7.69
500	23.9	155	58.6	290	7.07
600	30.6	155	77.0	290	6.08
700	39.5	155	86.5	290	5.47
800	40.9	155	97.1	290	5.02
900	50.8	155	111	290	4.29
1000	66.0	155	137	290	3.13
1100	79.8	155	162	290	2.20
1200	98.2	155	191	290	1.30
1300	107	155	207	290	0.919
1400	112	155	221	290	0.661
1500	124	155	239	290	0.366
1600	133	155	262	290	0.127
1700	140	155	275	290	0.0450
1800	151	155	294	290	0.00320
1900	162	155	305	290	0.027
2000	175	155	318	290	0.1184

The plot of force on x-coordinate axis and sum of squares in difference of simulation and measured data along y-coordinate axis gives a curve of parabolic shape. The point where the curve converges is the minimum of the error. The force corresponding to this point is the operating force for a measured reading

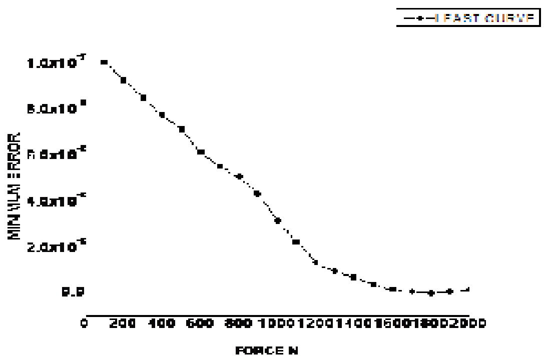

Fig 5 Least square plot

From above graph minimum of functional is at $3.20\text{x}10^{-11}$and corresponding force is 1800N

IV. CONCLUSION

The present work aimed at measurement of operating force using inverse FEM technique. As a matter of fact, machine members and real life structures are designed to subject some kind of loads. While designing machines and structures the operating forces are usually not known. Therefore, usually the design is based on estimated loads. For refinement of design the operating loads are to be determined accurately. The Inverse FEM is a hybrid experimental and numerical technique for measuring the operating loads.The method involves the forward finite element analysis on a machine or structural member for the range of loads. The deformation data obtained from forward finite element analysis and the data obtained from experimental using strain gauges helps us in predicting the operating loads. Therefore this analysis is based on measurement of actual data from the structure for estimating the operating force.The strain data from measurement for an applied load and the strain data obtained from finite element analysis at the corresponding points are used in Least square analysis. From the plot of error verses force the location where the error is minimum will give the applied Force. Therefore the inverse FEM technique is a powerful tool used for the measurement of the force in machines or structures in determining operating loads. Since the present work is carried out at static linear condition strain measurement is considered as experimental data.

V. REFERENCES

1 "The inverse identification problem and its technical application." Tadeusz Uhl Arch Appl Mech, Feb 2006

2 "Impact Force identification from wave propagation responses." M.T. Martin and J.F .Doyle: School of Aeronautics and Astronautics. Purdue University. U.S.A. Int. Journal for Impact Engg. Vol 18, No:1, May 1994.

3 "Bridge weigh-in-motion system development using static truck/dynamic bridge models." Sarah. K. Leming and Harold. L. Stalford. Sandia National Laboratories, University of Oklahoma. American Controls Conference, 2002. May 8-10, 2002.

4 "A Wavelet De convolution method for Impact force identification." J.F .Doyle. Professor. School of Aeronautics and Astronautics. Purdue University. U.S.A Experimental Mechanics. Vol 37, No:4,Dec 1997.

5 "Inverse finite element methods for force estimation and model recalibration" Philippe Maincon. Member, Safran Engineering Algorithms. 2006

6 ."An Interpretive method for moving force Identification." T.H.T.Chan., S.S.Law.and T.H.Yung. Dept of civil and structural engineering. The Hong Kong Polytechnic University and X.R.Yuan. Dept of Communication engineering. Shijiazhuang Railway Institute .Republic of China. Journal of sound and Vibration (1999) 219(3).503-524.

7 ."Finite element method v/s classical methods" Dr.H.S.Govinda Rao. New Age International Private Ltd, Publishers. First Edition-2007.

8 ."Text book of Finite Element Analysis". P. Seshu. Associate Professor Dept of mechanical Engineering. IIT. Bombay. Prentice-Hall of India Private Limited. New Delhi. First Edition-2003.

9 "Engineering Mathematics". Part IV. Dr.D.S.Chandrashekaraiah. Professor& Chairman (Rtd), Dept of Mathematics. UVCE. Bangalore. Prism Book Pvt Ltd, Bangalore. Third Edition-2004.

10 "Computational Inverse Techniques in Non-Destructive Evaluation". G.R.Liu. and X.Han. CRC Press, London. 2003.