Designing Experimental Set up for Validation of FEA

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Abstract

Engineering analysis is today of paramount importance in the product development cycle. FEA tools are one analytical computer aided engineering (CAE) tools, provide the engineer with the ability to analyze, model, simulate and optimize a design. FEA tools, when applied to a mechanical structure, offer the engineer insight into the stresses, deflections, model frequencies & mode shapes of the structure. FEA can be applied to other type of analysis, including heat transfer, electrostatic potential & fluid mechanics.

The physical problem typically involves an actual structure or structural component subjected to certain loads. The idealization of the physical problem to a mathematical model requires certain assumptions that together lead to differential equations governing the mathematical model. The FEA solves this mathematical model.

The experimental study is devoted to analyze the buckling analysis of bar. The experiment set up for the buckling which could be of linear elastic type. In this type since the experiment will not be destroy the sensor. Buckling occurs when a structure under an applied loading converts membrane strain energy into strain energy of bending.

In the present paper the author's attempt to elaborate the some of the issues & attempt to show how this could be addressed.

Key words: Buckling analysis, Experimental set up of buckling bar. FEA model, Linear elastic type buckling bar.

INTRODUCTION

The most fundamental underlying concept of FEM is the piecewise approximation of solution of a known geometry for which the characteristics are well established. This is infect refinement of the work of RITZ of 1908 showing the trial of getting solution and the piecewise approximation approach had shown by CURANT by 1943.

FEA tools provide a means to capture a 3D representation of the item to be manufactured. The model generation facilities of FEA tools tend to be fewer users friendly than those of CAD systems, and are usually intended for use by a highly trained engineer or analyst. Furthermore, the model generation facilities generally offer only limited support for model details.

FEA tools also include facilities for the capture of material properties for the item. While these facilities are often fewer users friendly than those of CAD systems, they tend to be more comprehensive and more versatile. Once the geometry of an item is defined, the item is partitioned into a number of small elements by overlaying a three-dimensional mesh on the item. A mathematical model based upon the element geometry and the defined material properties governs the response of each element to external stimulus (e.g., force or heat). The overall response of the item may be determined through the simultaneous solution of coupled element models. In this way, the static and dynamic response of the item is analyzed. Based upon this analysis, detailed reports showing stress, deflection, resonant mode shapes, and mode frequencies are generated.

Thus, the first requirement of FEM approach is discretization of the physical domain for which appropriate type of element is required to be selected. The beginner positions here, the problem of selecting the right type of element. Here, it is required to apprise the approach of continuity requirement and the applicability of this approach cannot be recourse, the alternate need to be apprise. Along with these, it is required to be apprising of various types of elements with appropriate classification.

Further, its need to be apprised of the scheme and mathematical procedure involve in optimal fitting of element equation. Here, broadly classified approach is like variation, weighted residual and direct approach in compassing range of algorithms needs to be briefed or elaborated as per the platform of discussion.

Further the integration of the piecewise solution is arrived at the system equation formulation and related issues of memory management and the algorithms for bandwidth management, the programming logic and optimization.

Most important and rather difficult and tricky issue is step in which load and boundary condition are imforced. Use of various special elements to represent typical features such as joint (bearing supports) and sliding surfaces (drawing, extrusion etc) such as spring, gap inertia elements.

As out line in earlier paragraph, the system of linear algebraic equation to be solved by number of algorithm and it is necessary here to apprise the comparative studies of these algorithm in terms of that static memory requirement, dynamic memory management, algorithmic operational efficiency and like.

Wide discussion of post processing part of the algorithm , appraising of the comparison with classical approach and distingant makes it Finite Difference Method. Infect, the complete aspect of FDM should be discussed all through the beginning in respect of the geometry complexity, material variation, fabrication features (joints, welding, soldering, and fastening).

Finite element analysis of elastic buckling bar:

Buckling analysis is a technique used to determine *buckling loads*-critical loads at which a structure becomes unstable-and *buckled mode shapes*-the characteristic shape associated with a structure's buckled response.

Two techniques are available in the Multi physics programs for predicting the buckling load and buckling mode shape of a structure: *nonlinear* buckling analysis and *Eigen value* (or linear) buckling analysis. Since these two methods frequently yield quite different results.

Nonlinear buckling analysis is usually the more accurate approach and is therefore recommended for design or evaluation of actual structures. This technique employs a nonlinear static analysis with gradually increasing loads to seek the load level at which your structure becomes unstable.(See Figure1 (a).)Using the nonlinear technique, model can include features such as initial imperfections, plastic behavior, gaps, and large-deflection response. In addition, using deflection-controlled loading, student can even track the post-buckled performance of the structure (which can be useful in cases where the structure buckles into a stable configuration.)

Eigenvalue buckling analysis predicts the theoretical buckling strength (the bifurcation point) of an ideal linear elastic structure. (See Figure 1(b).) This

method corresponds to the textbook approach to elastic buckling analysis: for instance, an Eigen value buckling analysis of a column will match the classical Euler solution. However, imperfections and nonlinearities prevent most real-world structures from achieving their theoretical elastic buckling strength.
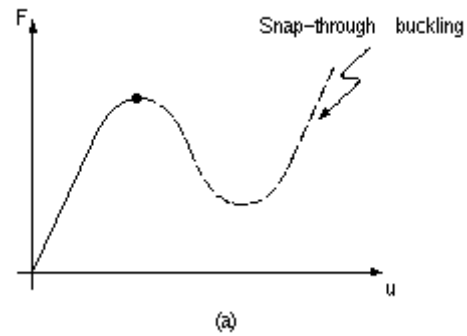

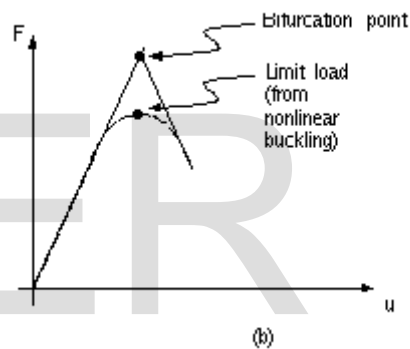**Fig -1 (a) Non linear load-deflection curve**

Fig -1 (b) Linear (Eigenvalue) buckling curve

Eigen value (linear) buckling analysis generally yields *unconservative* results, and should usually not be used for design of actual structures. So first decide that eigenvalue buckling analysis is appropriate for particular application.

Here first, we must define the model geometry, material properties, element types, and element real constants. Create the model in appropriate dimensions by creating nodes in global or local coordinate system; the bar has a cross-sectional height h, and area A. This is where the actual model is drawn in 1d (line) space in the appropriate units (M, mm, in, etc.). A point to be noted is that if a model is drawn in mm for example and the material properties are defined in SI units, then the results will be out of scale by factors of 1×10^6. Defining the material properties, i.e. the Young's modulus, Poisson ratio, the density, and if applicable, the coefficients of expansion, friction, thermal conductivity, damping effect, specific heat etc
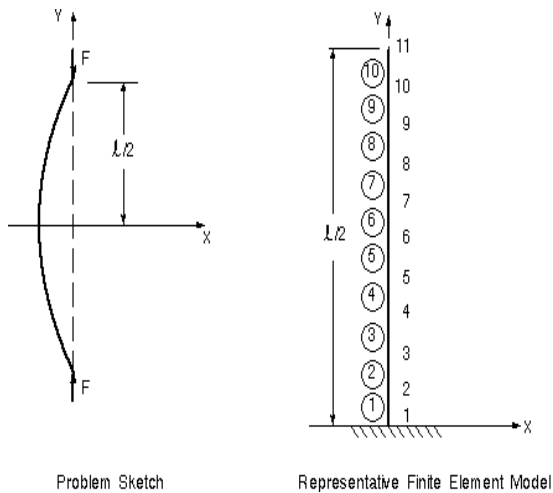
Fig-2 Diagram of Beam with Hinged Ends

Material properties may be linear, isotropic or orthotropic, and constant or temperature-dependent. To define the element type for this problem student can select 2D elastic buckling, 2D plastic buckling element. Defining the mesh density, this may be done by manually defining the number of elements along the lines of the model, thus customizing the number of elements & meshing the model. For element real constant, define the beam height, area, moment of inertia about x-y axes and also z-axes. The boundary conditions become free-fixed at bottom of the end. A total of 10 master degrees of freedom in the X-direction are selected to characterize the buckling mode. Determine the critical buckling load of an axially loaded long slender bar of length ℓ with hinged ends. Unit loads are usually sufficient (that is, actual load values need not be specified). The eigenvalues calculated by the buckling analysis represent buckling load factors. Therefore, if a unit load is specified, the load factors represent the buckling loads. All loads are scaled. Use larger applied loads if eigenvalues exceeds this limit.) . Eigenvalues buckling analysis requires the stress stiffness matrix to be calculated. Note that eigenvalues represent scaling factors for all loads. If certain loads are constant (e.g., self-weight gravity loads) while other loads are variable (e.g., externally applied loads), student need to ensure that the stress stiffness matrix from the constant loads is not factored by the eigenvalue solution. One strategy that student can use to achieve this end is to iterate on the eigensolution, adjusting the variable loads. Design optimization could be useful in driving this iterative procedure to a final answer. Solving for the matrix and then updating the displacement value for each node within the component or continuum follow the solution of the problem.

Experimental set up of buckling bar:

The experimental set up for studying the buckling which could be of linear elastic type or linear plastic type. In linear elastic type since the experiment will not destroy the sensor. Strain gauges should be considered as low cost transducer development means.

Instead if the study is intended for nonlinear plastic buckling, one should think of non-contact measurement system as the bar for study is subjected to plastic deformation & therefore cannot be reused & that large deformations are occurring. Further the measurement of deformation should be of two different natures (1) static & (2) dynamic. As far as the linear elastic studies are concerned strain gauges are reasonably good transducers for static and dynamic measurement.

For large deformations traditional approach of stress code is reasonable for static measurement of deformation. For dynamic measurement of large deformations fine greed printing with low to medium speed photographic technique could be examine.

MEMS technology based miniature size sensors should also be considers which are having integrated signal conditioning, signal processing, and microprocessor and computer interface ready. The setup adopted at author's place for experimental validation of linear elastic buckling test makes use of strain gauge sensors with interface electronics and digital signal processors based on DSP chip 2105 from analog device.
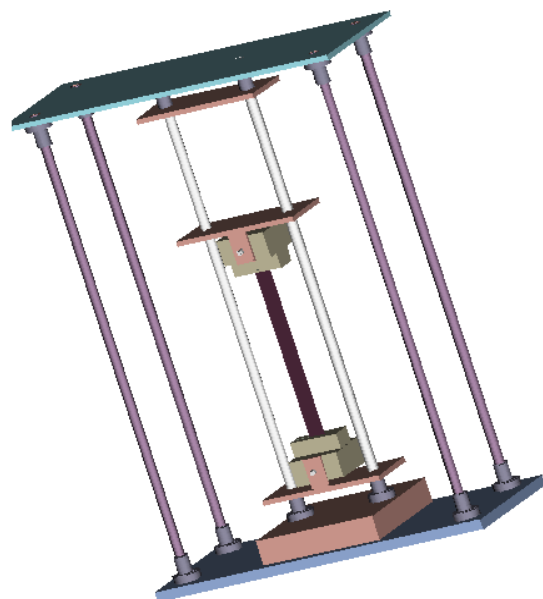

Fig-3. 3D-Model of Buckling Bar

3D Model of buckled bar as shown in Fig.3. Which wooden rectangle bottom plate gives the plate form and upper plate provides the enough height, four stainless steel pipes with polished surface at all corners provide the height and stiffness of the model. At middle of the model, main buckled parts are available with two-guide bar of stainless steel pipe fixed by flange prepared from 50-mm diameter mild steel rod. Strip, which we want to buckle, is hinged with two wooden blocks, Interface with DSP & computer as shown in Fig.4.

Electromagnet with torque of 20 kg, 230 volt supply is provided at the top of the model and applied impact load to the strip as we supply power. Strain gauges are bonded at 10cm distances on bothside of strip (Eight Strain gauges) by adhesive method of using araldite for interfacing strain gauge to DSP (Digital Signal Processor), we prepared circuit with the help of operational amplifier LM324 with two cascading.

Resistance : standardized values, 120Ω. A resistance tolerance is often quoted for example +0.25% and −0.25%.

Linearity : measurements are accurate within 0.1% up to 4000με, and within 1% upto 10000με.

Breaking strain : 20000 to 25000με.

Fatigue life : Upto 10^7 strain reversals

Temperature compensation: normally gauges are available with automatic compensation that matches the temperature expansion coefficient (θ_t) of one of the three most commonly used construction metals:

General purpose steels with $\theta_t=11x10^{-6}$ per °c ($6.1x10^{-6}$ per °F)

Stainless steels with $\theta_t=17x10^{-6}$ per °c ($9.5x10^{-6}$ per °F)

Aluminum with $\theta_t=23x10^{-6}$ per °c ($12.8 x 10^{-6}$ per °F)

Some gauges compensated for use on titanium, magnesium
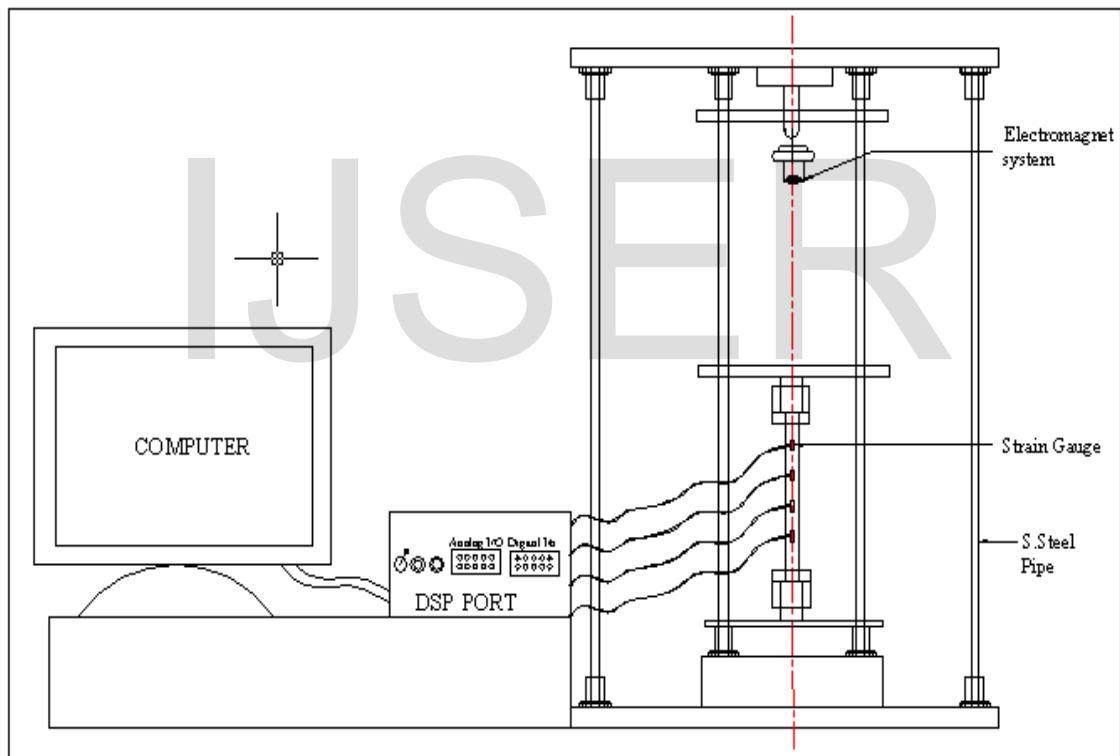

Fig.4 Schematic Diagram of Buckling Bar Set-up

DSP is interfaced with computer by programming to get signal from strain gauges; we plot the result on computer. Specifications of strain gauge analog amplifier and DSP are as follows.

Strain Gauge Specification:
Base : Bakelite
Greed size : 5mmx10 mm
Gauge factor : Approximately 2

DSP (Digital Signal Processor):
Overall dimensions : 237 MM. 185 MM. 44mm.
DSP processor chip : Analog 2105.
External power requirements : 2 x12 volt, 250 MA (maximum).
No. Of analog input channels: 8
Input resistance for analog input channel: 3000 ohm (minimum) at input /output.
Output resistance for analog output channel : Less than 10 ohm.
Digital input /output channel width: 8 bits.

Digital bus width for PC communication channel
Width   : 8 bits.
Communications: LPT port-based interface to PC, ,
serial synchronous port (sport) for other DSP PC
based monitor program.

Specification Of Interface Electronic:

The LM324 series are low cost, quad operational
amplifiers with true differential inputs.
Operational amplifier   : LM 324
Single supply operation : 3V to 32 V
Low input bias currents : 100 nano a maximum
Vcc   : 5V
Gain factor   : 15 (cascading two channels)
Junction temperature T_J : 150 °c

Procedure of experiment:

The strip material selected for linear elastic
buckling experiment verification's is anchored at
bottom end of setup that has angular freedom in x-y
plane and all linear x, y, z freedom arrested .The other
end of strip is connected to hinge that has angular
freedom in x-y plane and linear freedom in z plane,
while linear x, y freedom is arrested.

Strain gauges are fixed at selected points to sense
deformation and the signal is processed through digital
signal processor that in turn communicates to computer
for onward analysis. As load is applied, strip is
buckled, strain gauge mounted on the strip connected
to DSP through LM324 transmit the deflection data to
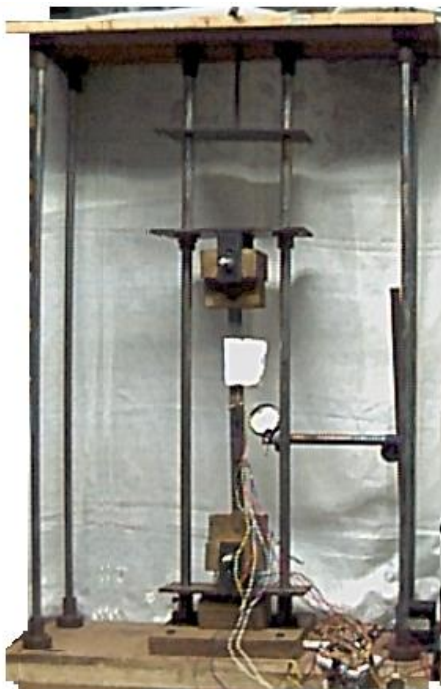computer. Fig.5 shows experimental set up.

Fig.5 Experiment set up of buckling bar.

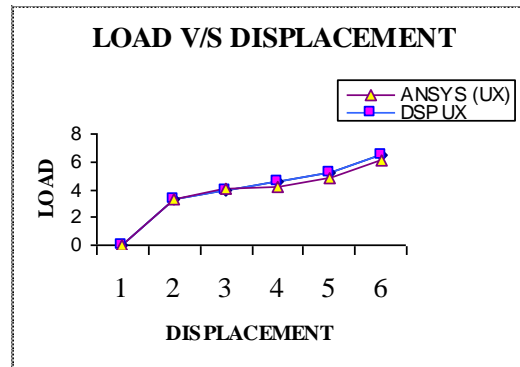### Experiment result and validation with ANSYS.

Fig.6. Graph of load v/s displacement

The experimental results will be used to directly
evaluate the effectiveness of the buckled strip setup.
Calculation of the deformation of the strip by the
following design methods will be considered:

1. Using the analysis software for simulation.
2. By practical performance on the set-up.
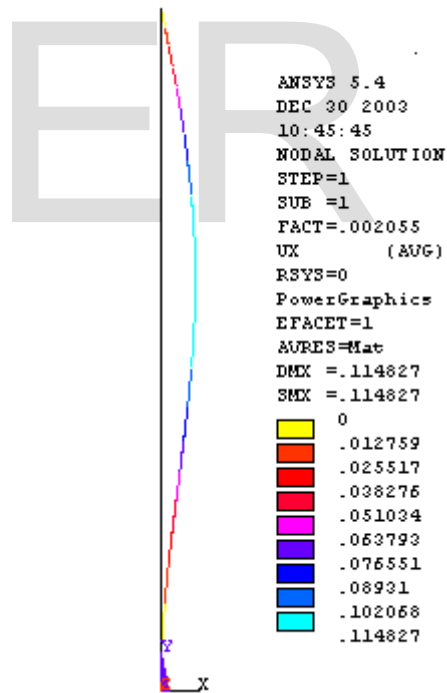3. Using the conventional buckling theory

Fig.7.Nodal solution in ANSYS graphic window.

Conclusion

In this paper attempted to show that FEA experiment is
simple to carry out, and that such experiments have a
sufficiently large range of application for engineering
professionals.

By adopting a practical approach it would be possible to expand, to a substantial degree, the arsenal of experimental tools used in science and engineering education..Authors have attempted to show that FEA experiment is simple to carry out, and that such experiments have a sufficiently large range of application for engineering students.

Acknowledgment

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