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To Optimize the Deflection of Beams by Conducting Bending Test Using Ansys Workbench 15

Mulayam Kumar [1], Dr. Simant[2], Vijay Gupta[3]
PG Scholar[1], Director at S.I.T.M B.B.K[2],Assistant Professor[3],
[1,2]Department of Mechanical Engineering, Sagar Institute of Technology and Management, Uttar Pradesh, India
[3]Department of Mechanical Engineering, B.B.D.N.I.T.M LUCKNOW, Uttar Pradesh, India

ABSTRACT

The present work has been carried out to study the effect of the varying the load at different materials (Aluminium Alloy 7075-T6, stainless steel 305 and Structural Steel 345w) on deflection. The simply supported beam has been subjected to varying load 5000N – 10000N and cantilever beam has been subjected to varying load 500N-1000N. The result obtained is in form of Directional Deflection and Equivalent Stresses. This analysis is done by the ANSYS Workbench 15.0 software under the static structural analysis further this result has been optimized using TAGUCHI METHOD using MINITAB17.
Keywords : Beams, Workbench 15, Aluminium Alloy, ANSYS, Finite Element Analysis

I. INTRODUCTION

Beam is a half mast or horizontal structural limb casing a gap among one or additional supports, & carrying vertical loads across (transverse to) its longitudinal axis, as a purlin, girder or rafter. Three main kinds of beams are:

- Simple span , supported at both ends
- Continuous , supported at more than two points
- Cantilever , supported at one end with the other end overhanging & free.

Simply supported beam:

A simply supported beam is a type of beam that has pinned support at one end & roller support at the other end. Depending on the load applied, it undergoes shearing & bending. It is the one of the simplest structural elements in existence.

Cantilever beam:

A cantilever beam is fixed at one end & free at other end. It can be seen in the image below.

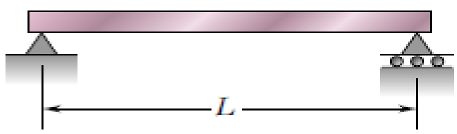

Figure 1: Simply Supported Beam [18]

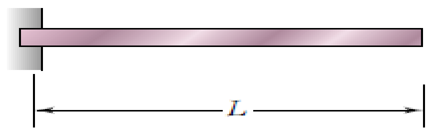

Figure 2: Cantilever Beam[18]

Overhanging beam: An overhanging beam is a beam that has one or both end portions extending beyond its supports. It may have any number of supports. If viewed in a different perspective, it appears as if it is has the features of simply supported beam & cantilever beam.

Continuous beam: A continuous beam has more than two supports distributed throughout its length. It can be understood well from the image below.

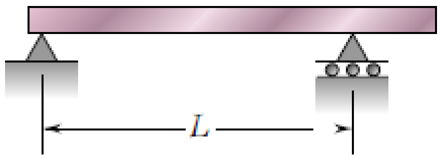

Figure 3: Overhanging Beam [18]

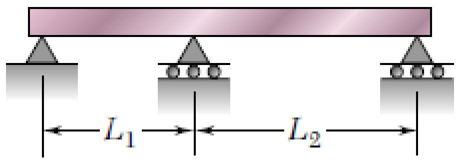

Figure 4: Continuous Beam[18]

Fixed beam:

As the name suggests, fixed beam is a kind of beam whose both ends are fixed.

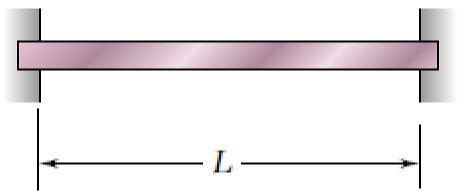

Figure 5: beam whose both ends are fixed.

II. METHODOLOGY

Ansys are founded on the concept of FINITE ELEMENT ANALYSIS. It is an approximate solution of Engineering Problems . There are three main approaches to constructing an approximate solution founded on the concept of FEA:

- **Direct Approach** This approach is used for relatively simple problems, and it usually serves as a means to explain the concept of FEA and its important steps.
- **Weighted Residuals** This is a versatile method, allowing the application of FEA to problems that's functional cannot be constructed. This approach directly utilizes the governing differential equations, such as those of heat transfer and fluid mechanics.
- **Vibrational Approach** This relies on the calculus of variations, which involves extremizing a functional. This functional corresponds to the potential energy in structural mechanics.

NODES [19]:

The transformation of the practical engineering problem to a mathematical representation is achieved by discretizing the domain of interest into elements (subdomains). These elements are appended to each other by their "common" nodes. A node specifies the coordinate location in space where degrees of freedom and actions of the physical problem exist. The nodal unknown(s) in the matrix system of equations represents one (or more) of the primary field variables. Nodal variables assigned to an element are called the degrees of freedom of the element.

ELEMENTS:

Depending on the geometry and the physical nature of the problem, the domain of interest can be discretized by employing line, area, or volume elements. Some of the general elements in FEA are shown in Fig. 4.1each element, discern by an element number, is defined by a specific sequence of global node numbers. The specific sequence (usually counter clockwise) is founded on the node numbering at the element level.The node numbering sequence for the elements shown in Fig.

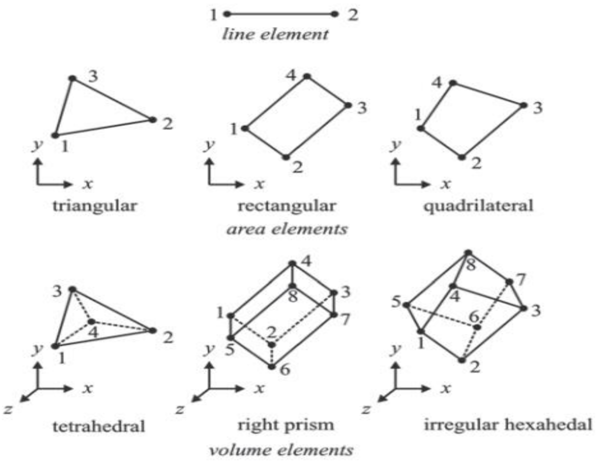

Figure 6 : Description of line, area, and volume element with node number at element Level [19]

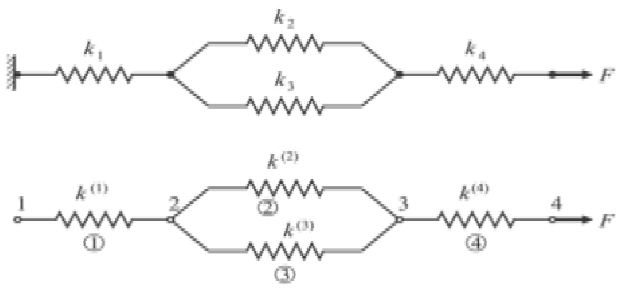

Figure 7: system of linear spring (top) and corresponding FEA model (bottom)[19]

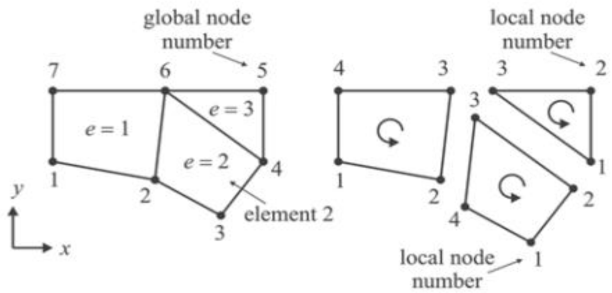

Figure 8: Discretization of a domain: element and node numbering[19]

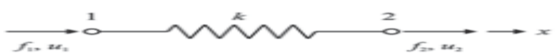

Figure 9: Free body Diagram of a linear spring Element

MATERIAL PROPERTIES:

For each element type, there are a minimum number of required material properties. This number depends on the kind of analysis. The material nature may be:

- Linear or nonlinear.
- Isotropic, orthotropic, or anisotropic.
- Temperature dependent or independent.

All material nature can be input like functions of temperature. Some natures are called linear properties because typical solutions with these natures need only a single iteration. This means that the properties being used are neither time nor temperature dependent, and thus remain constant throughout the analysis.

In the presence of variable material properties, the nonlinear characteristics of the properties must be specified. For example, a material exhibiting plasticity, vis-plasticity, etc., requires the specification of a nonlinear stress-strain relation. Each material property set has a reference number, the same as the element kinds & real constants The Help System should be consulted for the specification of nonlinear material properties.

III. CALCULATION AND RESULTS

CASE 1- SIMPLY SUPPORTED BEAM WITH UNIFORM DISTRIBUTED LOAD

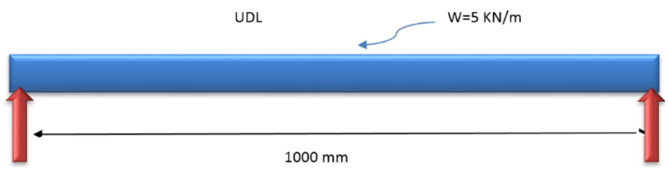

Figure 10 : Bending test Setup

Mathematical calculation:

According to given data we can calculated the maximum deformation (Y), Bending Moment (M) and stress (σ)

- W = 5 KN/m

  = 5 * 1000 = 5000 N
- L = 1 m = 1000 m
- b = t = 40 mm

- $E = 210 * 10^3$ N/ mm^2
- $I = bt^3 / 12$

  $= 213333.33$ mm^4

  $Y = -5wl^4/ 384 * EI$

  $= -1.4532$ mm
- $M = (wL^2) /8$

  $= (5*1000*1000)/8$

  $= 625000$ N-mm
- $\frac{M}{I} = \frac{\sigma}{y}$

  $\sigma = 58.59\ N/mm^2$

CASE 2- SIMPLY SUPPORTED BEAM WITH CENTRAL LOAD.

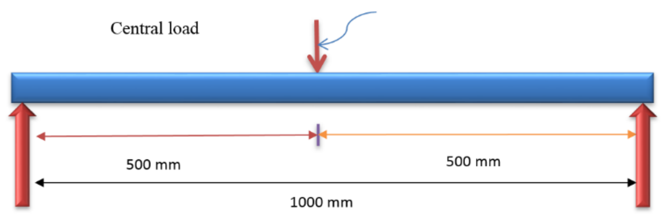

Figure 11: Bending test Setup

Mathematical Calculation

According to given data we can calculated the maximum deformation (Y), Bending Moment (M) and stress (σ)-

- W = 5 KN/m

  = 5 * 1000 = 5000 N
- L = 1 m = 1000 mm
- b = t = 40 mm
- $E = 210 * 10^3$ N/ mm^2
- $I = bt^3 / 12$

  $= 213333.33$ mm^4

  $Y = -wl^3/ 48 * EI$

  $= -2.325$ mm
- $M = (wL^2) /4$

  $= (5*1000*1000)/4$

  $= 1250000$ N-mm
- $\frac{M}{I} = \frac{\sigma}{y}$

  $\sigma = 117.18\ N/mm^2$

Case 3- Cantilever beam with point load.

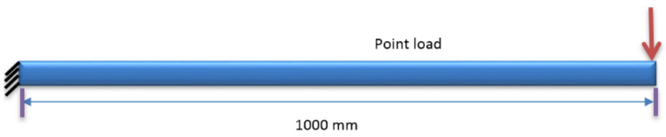

Figure 12: Bending test Setup

Mathematical Calculation:

According to given data we can calculated the maximum deformation (Y), Bending Moment (M) and stress (σ)

- W = 500 N
- L = 1 m = 1000 m
- b = t = 40 mm
- $E = 210 * 10^3$ N/ mm^2
- $I = bt^3 / 12$

  $= 213333.33$ mm^4

  $Y = -WL^3/ 3 * EI$

  $= -3.720$mm
- $M = (WL)$

  $= (500*1000)$

  $= 500000$ N-mm
- $\frac{M}{I} = \frac{\sigma}{y}$

  $\sigma = 46.88\ N/mm^2$

TAGUCHI METHOD

Taguchi Method is a new engineering design optimization methodology that improves the quality of existing products and processes and simultaneously reduces their costs very rapidly, with minimum engineering resources and development man-hours. The Taguchi Method achieves this by making the product or process performance "insensitive" to variations in factors such as materials, manufacturing equipment, workmanship and operating conditions.

Taguchi methods (Japanese) are statistical methods, or sometimes called robust design methods, developed by Genichi Taguchi to improve the quality of manufactured goods, and more recently also applied to engineering,[2]

Taguchi's use for manufacturing

Taguchi realized that the best opportunity to eliminate variation of the final product quality is during the design of a product and its manufacturing process. Consequently, he developed a strategy for quality engineering that can be used in both contexts. The process has three stages:

- System design
- Parameter (measure) design
- Tolerance design

The significant thermal behaviour of the compound was determined from the initial degradation temperature which is taken as the temperature at which degradations started and the residue weight percentage denoted as char.

Initial degradation temperature was 150^{0}C and final degradation temperature was 600^{0}C.

VALIDATION OF ANSYS RESULT USING TAGUCHI METHOD STRUCTURAL STEEL 345W

Selecting factors are length, section and load for taguchi analysis.

Table 1: For Structural Steel 345w

Factor	Length (m)	Section	Load (N)
level			
1	0.5	I-section	500
2	1	Rectangular	600
3	1.5	Square	700

After applying taguchi technique for L9 Array for three factors, The table given bellow

IV.CONCLUSION

The present work has been carried out to study the deflection of beam on applied load of 5000 N to 10000 N of simply supported beam with UDL, simply supported beam with point load and applied load of 500N to 1000N on cantilever beam. The calculation has been made theoretically as well as using ANSYS WORKBENCH 15 and TAGUCHI METHOD. Taguchi method applied on the result of deflection for validation of deflection result use for manufacturing technique. From the obtained result it can be concluded that out of Aluminum alloy 7075-T6, Gray cast Iron, Stainless steel 305 and Structural Steel 345w, has minimum deflection and maximum bending stress in all loading conditions.

A. Material Study:

I. We took the different materials Aluminium Alloy 7075-T6, stainless steel 305and Structural Steel 345w.

II. specified the material properties, applied meshing and boundary condition.

B. Mathematical Investigation:

According to beam and load type we applied the mathematical formula and then got the deflections and stresses.

C. Ansys Investigations:

We got very closer values of the deflections and stresses through the ansys workbench.

D. Suggestions for Future Study:

I. We can investigate to take any other cross-sections or different length of beams.

II. This can be extended to include coating of any materials, composite materials etc.

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