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The bending test on Beam of Aluminium alloy, Gray cast iron, Stainless steel and Structural steel using Ansys Workbench 15 at High Strain Rate

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ABSTRACT: In this work we presents the result of effect of the varying the load at different materials (aluminum alloy, grey cast iron, stainless steel and structural steel). The simply supported and fixed beam have been subjected to varying load 8000N – 10000 N. cantilever beam has been subjected to varying load 800N-1000 N. we got the result in form of Directional Deflection and Equivalent Stresses. This analysis is done by the ANSYS Workbench 14.0 software under the static structural analysis. The results obtained via simulation and mathematical formula based on type of beam and boundary conditions.

KEYWORDS: FEM, Impact of varying Loads, ANSYS Workbench.

I. INTRODUCTION

Past few decades have seen an increasing application of Computer Aided Engineering (CAE) for simulation of bending phenomenon particularly due to development of high computing machines and parallel computing techniques. The increase in safety standards can be attributed to the improvement of structural without bending performance through Finite Element Analysis (FEA). The effect of load on structures is one problem and the second one is of prime importance is the safety of occupants. It seems that occupant safety simulation offers today reasonably accurate result which can save a lot of testing time and overall decision cycle time. Beam is an inclined or horizontal structural member casing a distance among one or additional supports, and carrying vertical loads across (transverse to) its longitudinal axis, as a purlin, girder or rafter. Beams use as shaft with circular cross section which may be supported at both ends with bearing and carrying a load like that pullies, Gears, Dead Weights etc. Therefore in this paper we compared the Mathematical and Ansys Workbench results, plotted the graphs between Mathematical and Ansys Analysis and determined the percentage errors with the help of Formulas and Ansys Workbench 15.0

II. FINITE ELEMENT ANALYSIS OF BEAM

Finite element analysis (FEA) is one of the efficient and well-known numerical methods for various engineering problems. FEA was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems as cited by Swatantra and Pradeep [1]. For the last 30 years it has been used for the solution of many types of problems. FEA has become an integral part of design process in automotive, aviation, civil construction and various consumer and industrial goods industries the corporations to launch reasonably priced products in short time, making them to rely more on virtual tools (CAD/CAE) accelerate the design and development of products. FEA tools are being used to analyse multi-disciplinary problems, including but not limited to structures, thermal and fluid flow, NVH applications, biotechnology etc. [2]. FEA is used to predict multiple types of static and dynamic structural responses.

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 4, Issue 4 , April 2017

III. ANSYS DEFLECTION ANALYSIS OF BEAM

The commercial software package ANSYS used as a FEA tool in the stress analysis. The ANSYS program is a powerful, multi-purpose analysis tool that can be used in a wide variety of engineering disciplines [3]. Using ANSYS software can avoid expensive and time-consuming development loops, so the design period is shortened [4]. There are three main approaches to constructing an approximate solution based 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.

IV. CALCULATION AND RESULTS

A. SIMPLY SUPPORTED BEAM WITH UNIFORM DISTRIBUTED LOAD (UDL)

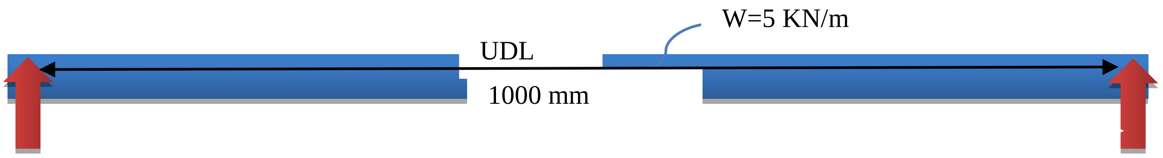

Figure 1: Bending test Setup.

- **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
- $\frac{M}{I} = \frac{\sigma}{y}$
  $\sigma = 58.59\ N/\text{mm}^2$

- **MATHEMATICAL RESULT**

Directional Deflection	**-1.4532 mm**
Equivalent Stress	**58.59 Pa**

- **ANSYS ANALYSIS AND RESULT:**

Ansys Result Shown in the below figure –

ISSN: 2350-0328
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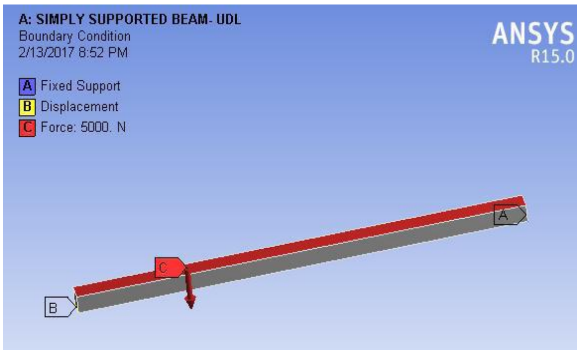


Figure 2: Boundary Condition

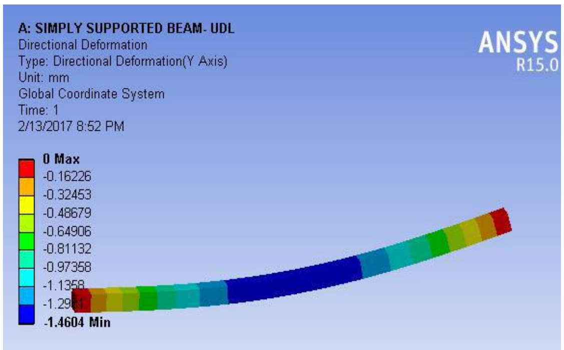


Figure 3: Directional Deformation Diagram

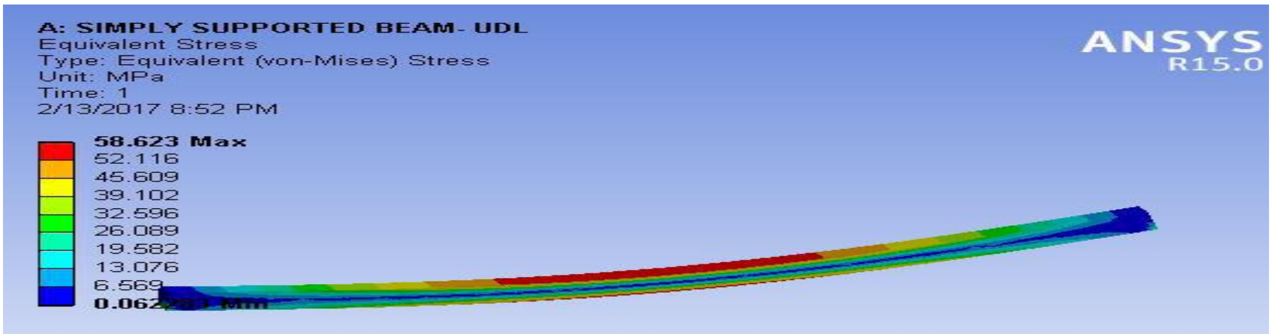


Figure 4: Bending Stress Diagram.

B. FIXED BEAM WITH UDL.

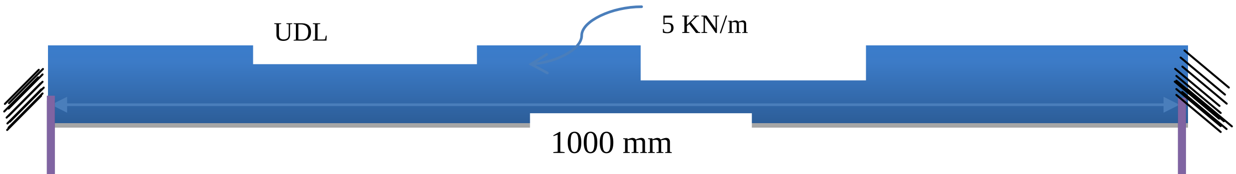


Figure 5: Bending Test Setup

➢ 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 = -WL^4/ 384 * EI
  = -0.290 mm
- M = (WL^2) /12
  = (5*1000*1000)/12
  = 416666.666 N-mm
- $\frac{M}{I} = \frac{\sigma}{y}$
  $\sigma = 39.062\ N/\text{mm}^2$

➢ MATHEMATICAL RESULT:

Directional Deflection	**-0.290 mm**
Equivalent Stress	**39.062 MPa**

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 4 , April 2017

➤ ANSYS ANALYSIS AND RESULT:

Ansys Result Shown in the below figure –

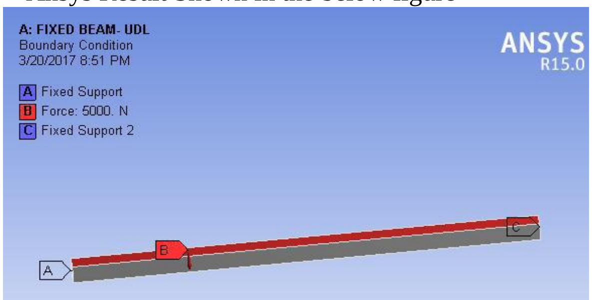


Figure 6: Boundary Condition

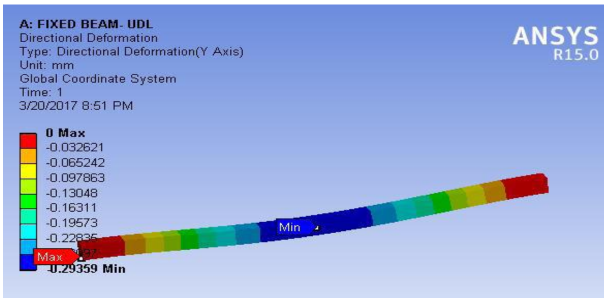


Figure 7: Directional Deformation Diagram

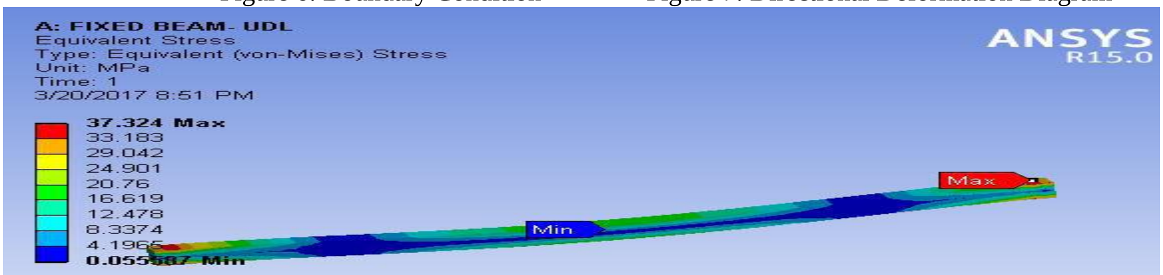


Figure 8: Bending Stress Diagram

C. CANTILEVER BEAM WITH POINT LOAD

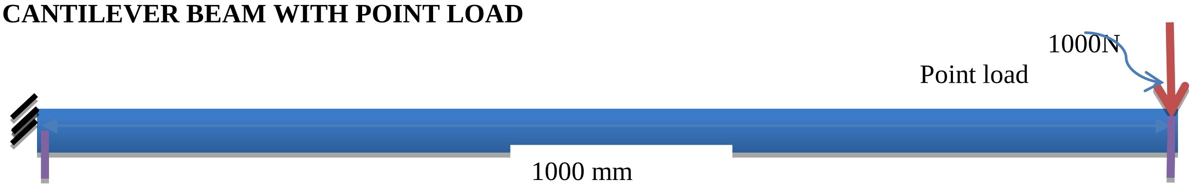


Figure 9: Bending test Setup

➤ MATHEMATICAL CALCULATION

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

- W = 1000 N
- L = 1 m = 1000 m
- b = t = 40 mm
- $E = 210 * 10^{3}\ N/mm^2$
- $I = bt^3 / 12$
  $= 213333.33\ mm^4$

- $Y = -WL^3 / 3 * EI$
  $= -7.442$ mm
- M = (WL)
  = (1000*1000)
  = 1000000 N-mm
- $\frac{M}{I} = \frac{\sigma}{y}$
  $\sigma = 93.750\ N/mm^2$

➤ MATHEMATICAL RESUL

Directional Deflection	**-7.442 mm**
Equivalent Stress	**93.750 MPa**

➤ ANSYS ANALYSIS AND RESULT

Ansys Result Shown in the below figure:

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 4 , April 2017

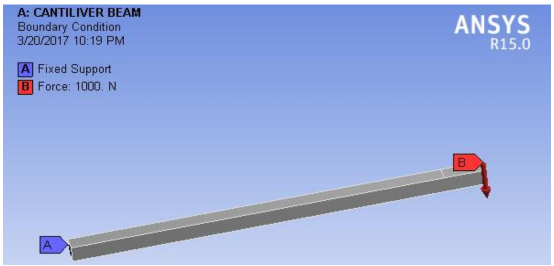


Figure 10: Boundary condition.

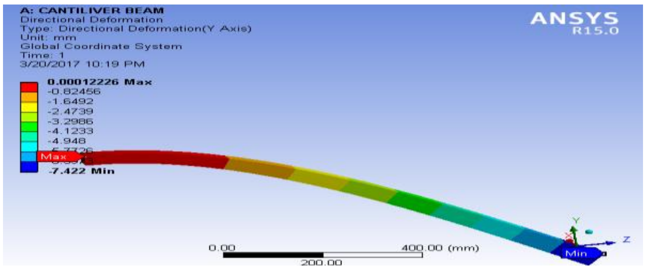


Figure 11: Directional deformation.

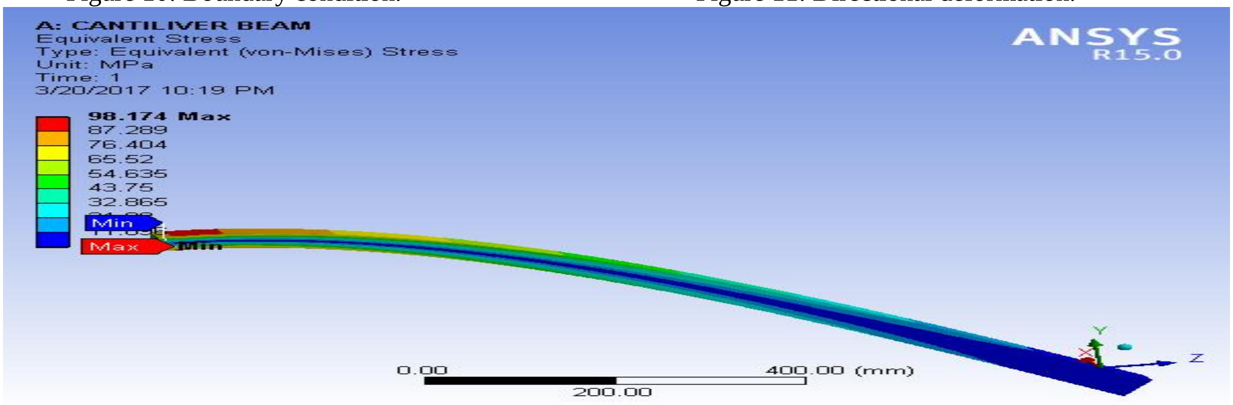


Figure 12: Diagram & Chart of Directional deformation at the path.

V. RESULT OF VARIOUS LOADS AT DIFFERENT MATERIALS

A. SIMPLY SUPPORTED BEAM-UDL: We are showing the impact of load (8000-10000 N) at Deferent material for the simply supported beam which is subjected to Uniform distributed load.

- **ALUMINIUM ALLOY:** Aluminium Alloy have young modulus **(**E= 71 GPa), poison ratio (υ= 0.33) and product of young modulus and moment of inertia (E×I =1.5146×10^{10}N-mm^2).

Table 5.1: Impact at Aluminium

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys Deflection Y_{Ansys} (mm)	Theoretical Stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys Stress σ_{Ansys} (N/mm^2)	Percentage Error Deflection Y_{Error}	Percentage Error Stress σ_{Error}
i	8000	-6.877	-6.9116	93.750	93.796	-0.503	-0.049
ii	9000	-7.737	-7.755	105.468	105.52	-0.233	-0.049
iii	10000	-8.596	-8.639	117.187	117.25	-0.500	-0.054

- **GREY COST IRON:** Grey Cost Iron has young modulus **(**E= 110 GPa), poison ratio (υ= 0.28) and product of young modulus and moment of inertia (E×I =2.3466×10^{10}N-mm^2).

Table 5.2: Impact at Grey Cost Iron.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys Deflection Y_{Ansys} (mm)	Theoretical Stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys Stress σ_{Ansys} (N/mm^2)	Percentage Error Deflection Y_{Error}	Percentage Error Stress σ_{Error}
i	8000	-4.439	-4.460	93.750	93.796	-0.473	-0.049
ii	9000	-4.993	-5.018	105.468	105.52	-0.501	-0.049
iii	10000	-5.548	-5.575	117.187	117.25	-0.487	-0.054

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 4, Issue 4 , April 2017

- **STAINLESS STEEL:** Stainless Steel have young modulus **(**E= 193 GPa), poison ratio (υ= 0.31) and product of young modulus and moment of inertia (E×I =4.117×10^{10}N-mm^2).

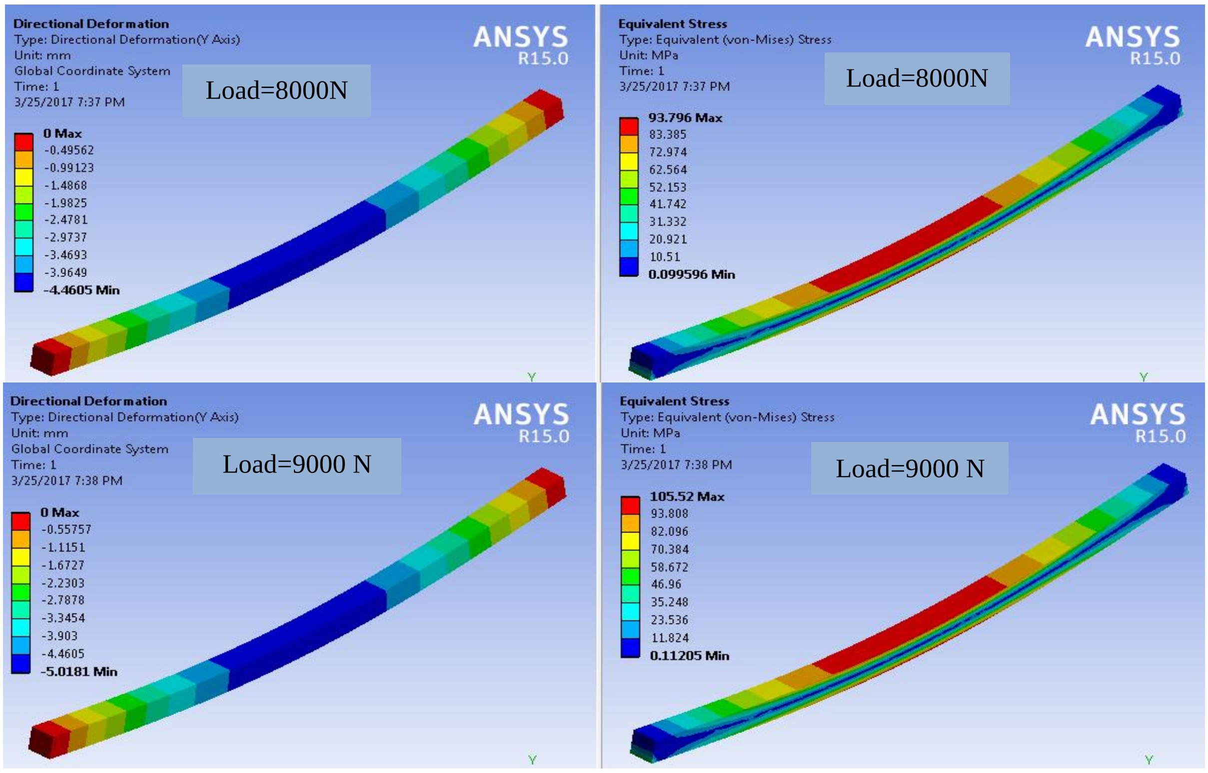
Table 5.3: Impact at Stainless Steel.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys Deflection Y_{Ansys} (mm)	Theoretical Stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys Stress σ_{Ansys} (N/mm^2)	Percentage Error Deflection Y_{Error}	Percentage Error Stress σ_{Error}
i	8000	-2.530	-2.542	93.750	93.796	-0.474	-0.049
ii	9000	-2.846	-2.860	105.468	105.52	-0.492	-0.049
iii	10000	-3.162	-3.178	117.187	117.25	-0.506	-0.054

- **STRUCTURAL STEEL:** Structural Steel have young modulus **(**E= 210 GPa), poison ratio (υ= 0.3) and product of young modulus and moment of inertia (E×I =4.479×10^{10}N-mm^2).

Table 5.4: Impact at Structural Steel.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys Deflection Y_{Ansys} (mm)	Theoretical Stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys Stress σ_{Ansys} (N/mm^2)	Percentage Error Deflection Y_{Error}	Percentage Error Stress σ_{Error}
i	8000	-2.566	-2.336	93.750	93.796	8.963	-0.049
ii	9000	-2.616	-2.628	105.468	105.52	-0.459	-0.049
iii	10000	-2.907	-2.920	117.187	117.25	-0.447	-0.054



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ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 4 , April 2017

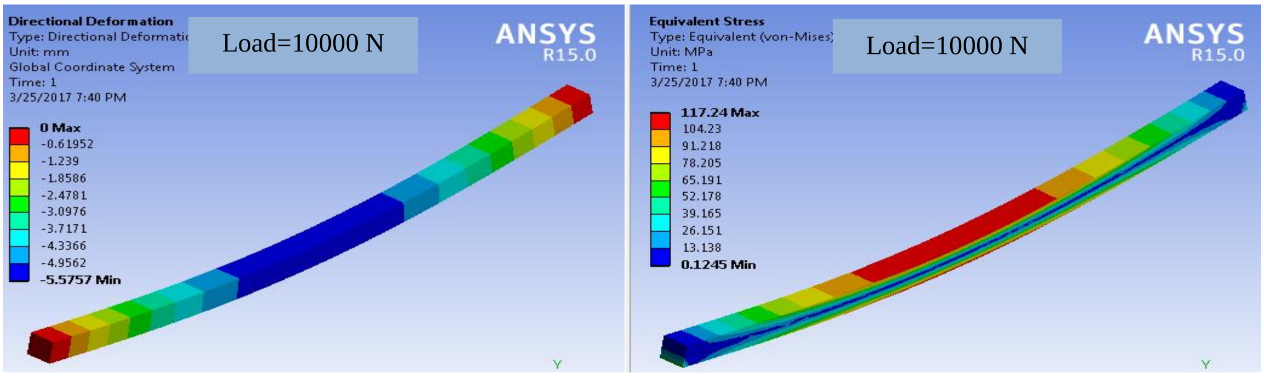


Figure 7.2: Impact of Loads at Grey Cast Iron for Simply Supported Beam Subjected to UDL

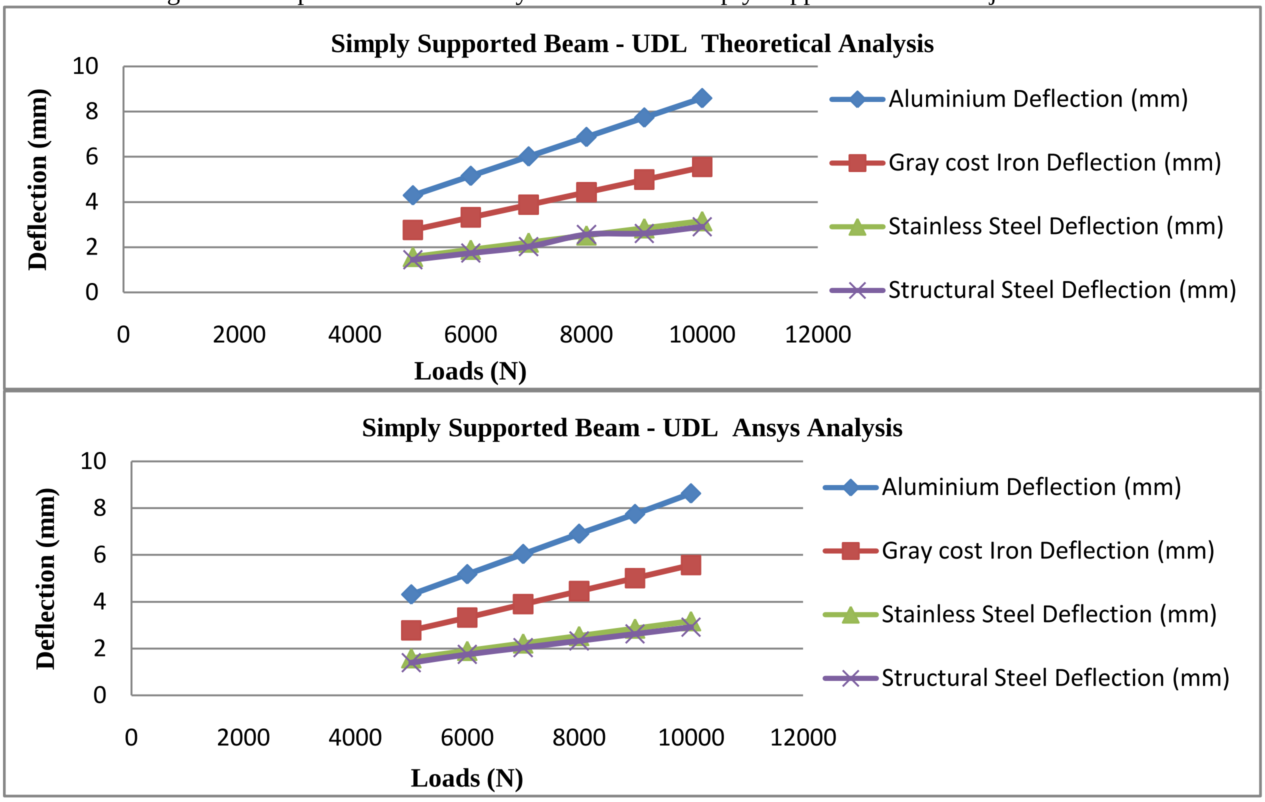


Figure 5.1: Graph Between Theoretical & Ansys Analysis for Simply Supported Beam Subjected To UDL.

B. CANTILEVER BEAM-POINT LOAD: We are showing the impact of load (800-1000 N) at Deferent material for the Cantilever beam which is subjected to point load.

- **7.4.1 ALUMINIUM ALLOY:** Aluminium Alloy have young modulus **(**E= 71 GPa), poison ratio (υ= 0.33) and product of young modulus and moment of inertia (E×I =1.5146×10^{10}N-mm^2).

Table 5.5: Impact at Aluminium.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys deflection Y_{Ansys} (mm)	Theoretical stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys stress σ_{Ansys} (N/mm^2)	Percentage error deflection Y_{Error}	Percentage error Stress σ_{Error}
i	800	-17.606	-17.547	75.000	78.539	0.003351	-0.04718
ii	900	-19.807	-19.74	84.375	88.356	0.003382	-0.047182
iii	1000	-22.008	-21.934	93.75	98.174	0.003362	-0.047189

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 4 , April 2017

- **STAINLESS STEEL:** Stainless Steel have young modulus **(**E= 193 GPa), poison ratio (υ= 0.31) and product of young modulus and moment of inertia (E×I =4.117×10^{10}N-mm^2).

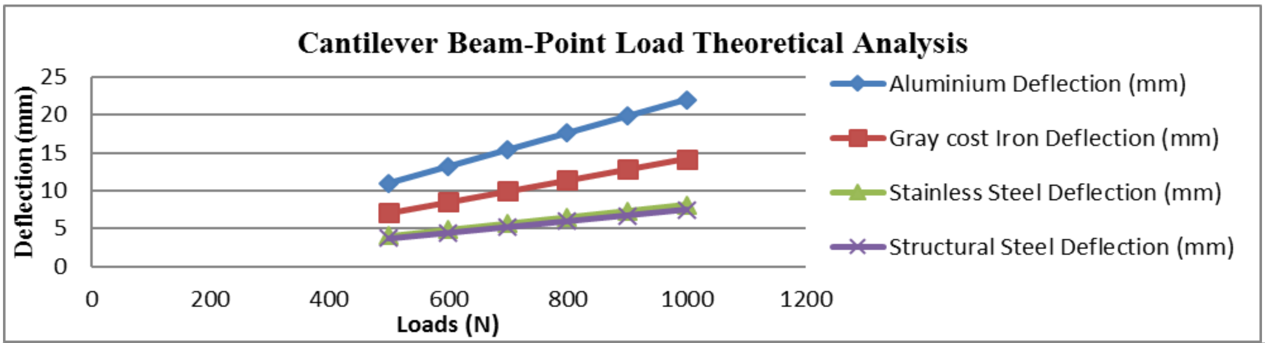
Table 5.7: Impact at Stainless Steel.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys deflection Y_{Ansys} (mm)	Theoretical stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys stress σ_{Ansys} (N/mm^2)	Percentage error deflection Y_{Error}	Percentage error stress σ_{Error}
i	800	-6.477	-6.458	75.000	78.539	0.002933	-0.04718
ii	900	-7.286	-7.266	84.375	88.356	0.002744	-0.047182
iii	1000	-8.096	-8.073	93.75	98.174	0.002840	-0.047189

- **STRUCTURAL STEEL:** Structural Steel have young modulus **(**E= 210 GPa), poison ratio (υ= 0.3) and product of young modulus and moment of inertia (E×I =4.479×10^{10}N-mm^2).

Table 5.8: Impact at Structural Steel.

S. N.	Load (N)	Theoretical Deflection $Y_{Theoretical}$ (mm)	Ansys deflection Y_{Ansys} (mm)	Theoretical stress $\sigma_{Theoretical}$ (N/mm^2)	Ansys stress σ_{Ansys} (N/mm^2)	Percentage error deflection Y_{Error}	Percentage error stress σ_{Error}
i	800	-5.953	-5.937	75.000	78.539	.00268772	-0.04718
ii	900	-6.697	-6.679	84.375	88.356	.00268777	-0.04718
iii	1000	-7.442	-7.422	93.75	98.174	.00268744	-0.04718



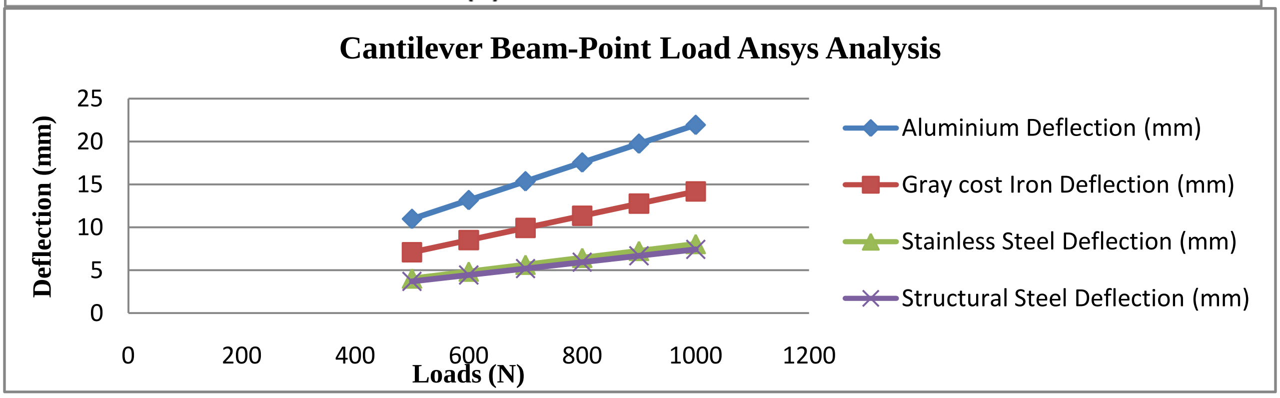


Figure 5.2: Graph Between Theoretical and Ansys Analysis for Cantilever Beam Subjected To Point Load.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 4 , April 2017

VI. CONCLUSION

The present work has been carried out to study the deflection and bending stress of simply supported beam, Fixed beam and cantilever beam under uniformly distributed load of 5000 N to 7000 N. The calculation has been made theoretically as well as using ANSYS WORKBENCH 15. From the obtained result it can be concluded that out of Aluminum alloy, Gray cast Iron, Stainless Steel and Structural steel, Structural Steel has minimum deflection and maximum bending stress in all loading conditions.

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