Computation & Analysis of Aluminum and Steel Structures by Using ABAQUS Software for Engineering Applications

Shabana Urooj*
Member IEEE
shabanaurooj@ieee.org

Monika Singh*
Member IEEE
monikasingh0404@gmail.com

Ruchi Dohare*
Member IEEE
ruchidohare@gmail.com

Ankesh Yadav*
ankeshyadav.92@gmail.com

Monika Singh*
singh.monikaj@gmail.com

Shilpi Ghosh*
ghosh.shilpi1991@gmail.com

Snigdha Sharma* *Member IEEE*
sharma.snigdha93@gmail.com

*Department of Electrical Engineering
School of Engineering
Gautam Buddha University
Greater Noida, Uttar Pradesh, India

Abstract: The area of material analysis demands wide research for variety of engineering applications in diversified fields. The aim of this study is to compute and investigate the properties of steel and aluminium by using specified softwareABAQUS-CAE(6-10).The impact of applied load and change in temperature for these two materials for hollow and solid cylinder, solid cantilever beam is computed and analysed. It is found that the change in certain parameter leads to the change in the dimensions of the chosen specimen which could be utilized as performance measure for variety of engineering applications viz., power system material, biomaterials and other industrial purposes.

Keywords- ABAQUS-CAE(6-10); mechanical; thermal; stress; displacement; Aluminum; Steel

1. INTRODUCTION

For designing power system it requires a lot of experimental and mathematical analysis [1]. While making system working effectively, it needs numerous efforts in selecting material that can withstand high pressure, temperature etc. However experimental and mathematical analysis may be often costly and time taking [1].The experimental and mathematical approach was outdated as the results were not precise and fast [1]. To make experiment results faster and precise software computation technique is used, thus making analysis of material structures easy. In the study model using finite element analysis software (ABAQUS-CAE) to the test mechanical and thermal behavior of the materials when they are exposed different temperature and pressure [2].

Mechanical and thermal tests on materials are performed for several reasons and for different engineering aspects. These results of mechanical and thermal tests are used in selecting materials for different engineering applications [3]. The mechanical and thermal behaviors of materials are often a primary concern for power system engineers. In power system, transmission line and devices etc. are exposed to numerous of conditions. Lightening strokes is one of the phenomena that affect the system stability. To protect the transmission line, lightning rods are mounted on the top of the churches and thus protect the line form thermal and mechanical effects [4].

The stress and displacement are results of applied forces on the specimen. Deformation in the materials is a result of applied pressure and temperature [3]. In this study, two different types of structures are considered, one is beam and other is cylinder of aluminum alloy and steel. Uniform pressure is applied on the top surface of the beam, displacement and stress on the structure its behavior due to applied stress is discussed. In the hollow cylinder one end is fixed and the other is kept free. Both the ends of hollow cylinder are kept at a temperature difference of 1 Kelvin. Graphs of displacement, stress, heat flux per area with respect to time are obtained. In this study number of factors is considered that effect thermal and mechanical testing like displacement, stress, heat flux per area, stress rate and temperature. The analysis is done by using software approach, however can also be carried out practically. In the study, efforts are made to visualize the effect of thermal and mechanical by software computational application.

To study the behavior of different structures of aluminum and steel, results are obtained on the ABAQUS–CAE(6-10) software and are visually and graphically interpreted[8,9]. This software computational application used in the study can be an alternative to the hard computing. ABAQUS-CAE provides complete solution for finite element modeling and visualization. ABAQUS-CAE supports familiar interactive computer-aided engineering concepts such as feature-based, parametric modeling, interactive and scripted operation, and GUI customization [5,8,9].

2. MATERIALS AND METHODS

The aim of this paper is to determine mechanical and thermal properties of two materials: aluminum alloy 1100 (UNS A9l100) and Steel A36 (ASTM A36).The material's chemical composition, mechanical properties and thermal properties are shown in Table I, Table II, and Table III respectively.

Table I: Chemical composition of the tested aluminum alloy A91100 and Steel ASTM A36 [wt%] [6]

Materials	**Al**	**Cu**		
A91100	99	0.2		
Material	Fe	C	Mn	Si
ASTMA36	98	0.29	1	0.28

Table II: Mechanical properties of the tested aluminum alloy A91100 and steel ASTM A36 [6]

Materials	**Modulus of Elasticity**	**Poission's ratio**
A91100	70	0.33
ASTM A32	207	0.3

Table III: Thermal properties of the tested aluminum alloy A91100 and steel ASTM A36 [6]

Material	**Coefficient of Thermal expansion[10^{-6}(^{0}C)$^{-1}$]**	**Thermal conductivity (W/m-K)**	**Specific heat (J/kg-K)**
A91100	23.6	222	904
ASTM A36	11.7	51.9	486

Aluminum alloy 1100 contains a minimum of 99.00% aluminum, and is also known as 'Commercially Pure Aluminum' [3,7]. Aluminum alloy 1100 has an excellent electrical conductivity, good formability and high resistance to corrosion, and is used where high strength is not needed. Aluminum alloy 1100 has the low density and excellent thermal conductivity common to all aluminum alloys [3]

ASTM A36 is Standard Specification for Carbon Structural Steel used as plates and bars. Mainly A36 used in riveted, bolted, or welded construction of bridges and buildings, and for general structural purposes.

The mechanical and thermal properties of aluminum and steel is studied using two types of structure i.e., cantilever beam and hollow cylinder.

A. Mechanical Analysis

The 3D structure of the cantilever beam is created. The length, breadth and height of the cantilever beam is taken 200mm, 20mm and 25mm respectively. The material parameters such as modulus of elasticity and poison's ratio for both materials aluminum and steel are defined.

One side of the beam is kept fixed and the other part of the beam is kept free. A uniform pressure of magnitude 0.5 Pascal is applied on the top surface of the beam. Meshing of beam is performed to generate a mesh with square hexahedral element of size 10mm. Simulation of the beam model of aluminum and steel is performed using ABAQUS-CAE software. Due to the pressure applied on the top surface of the beam, the deformation occurs in the structure of beam which is visualized by using the software. The displacement of the beam due to the applied pressure is plotted with respect to time. The stress occurring in the beam due to the applied pressure along x-axis, y-axis, z-axis, xy-axis, yz-axis, xz-axis are plotted with respect to time. Comparison of aluminum and steel using displacement and stresses graph is made.

B. Thermal Analysis

The 3D structure of a hollow cylinder made up of aluminum and steel are created. The height of the cylinder is taken 1m and the inner and outer radii of cylinder are 0.2m and 0.21m respectively. The material parameters such as mass density, modulus of elasticity, poison's ratio, thermal conductivity, coefficient of thermal expansion and specific heat for both aluminum and steel are defined.

One end of the cylinder is pinned and the other end is kept free. An ambient temperature of 273.15K is applied to the fixed end of the cylinder and the temperature of 274.15K is applied to the free end of cylinder. A surface traction load of magnitude 200KPa is applied to the free end of the cylinder. Meshing of cylinder model is performed to generate a mesh with square quadratic element of size 0.025m.

Simulation of the cylinder model is performed. Due to the difference in temperature between the two ends of cylinder, elongation of the material takes place and due to the applied traction load at the free end of the cylinder, deformation of the material takes place. Stresses occurring due to the increase in temperature as well as applied load along xx-axis, yy-axis, zz-axis, xz-axis, yz-axis, xz-axis the material aluminum and steel are plotted with respect to time. The heat flux per unit area due to the increase in temperature between the two ends of cylinder along x-axis, y-axis, z-axis for both aluminum and steel with respect to time.

The second simulation is performed on the aluminum and steel hollow cylinder to visualize the elongation in the cylinder structure due to the temperature difference applied across the two ends of the cylinder and the applied traction load at the free end of the cylinder.

3. RESULTS AND DISCUSSION

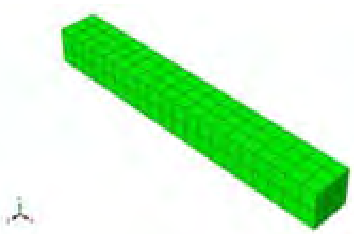

Fig. 1(a) Aluminum cantilever beam

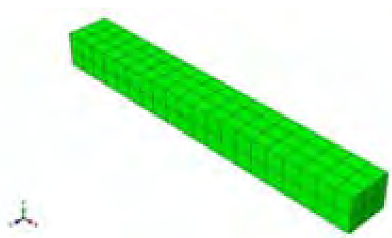

Fig. 1(b) Steel cantilever beam

Fig. 1(c) Aluminum hollow cylinder

Fig. 1(d) Steel hollow cylinder

Figure 1(a),1(b),1(c),1(d) shows the original meshed structure of aluminum beam ,steel beam, aluminum cylinder and steel cylinder respectively.

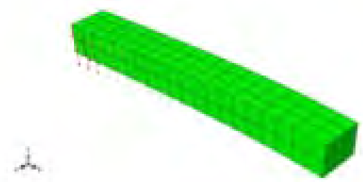

Fig. 2(a) Deformed aluminum cantilever beam

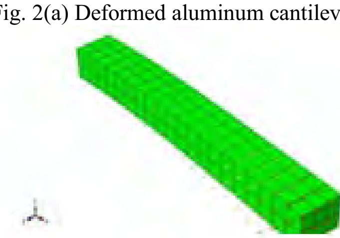

Fig. 2(b) Deformed steel cantilever beam

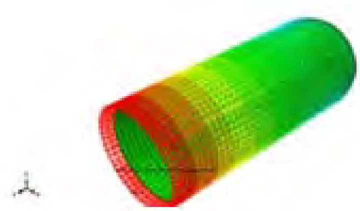

Fig. 2(c) Deformed aluminum cylinder

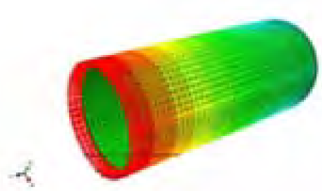

Fig. 2(d) Deformed steel cylinder

Figure 2(a), 2(b) shows the deformed structure of aluminum and steel beam respectively due to the applied pressure on the beam. Fig 2(c), 2(d) shows the elongated structure of aluminum and steel cylinder respectively due to the applied temperature difference across the two ends of the cylinder. The red region shows the maximum elongation and the blue region shows the minimum elongation. The elongation observed in aluminum cylinder is 0.67m and in steel cylinder is 0.3m.

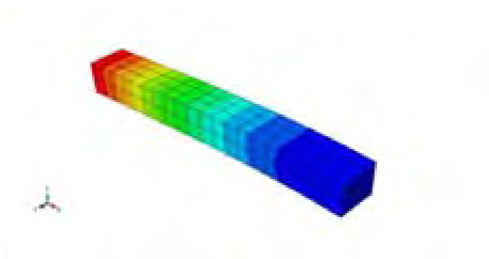

Fig. 3(a) Stresses in aluminum cantilever beam

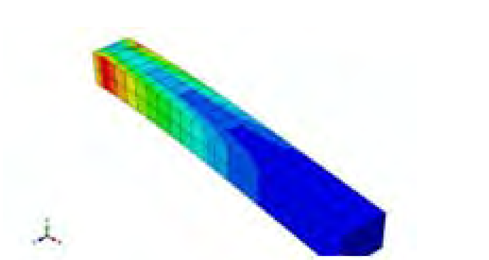

Fig. 3(b) Stresses in steel cantilever beam

Fig. 3(c) Stresses in aluminum cylinder

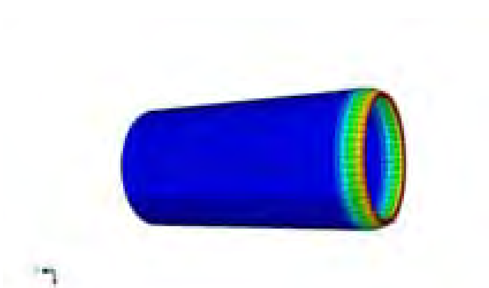

Fig. 3(d) Stresses in steel cylinder

Fig. 3(a),3 (b), 3(c) and 3(d) shows the different stress region on the surface of the aluminum beam, steel beam, aluminum and steel cylinder respectively. The red region shows the maximum stress region while the blue region shows the minimum stress region.

Table IV: The maximum and minimum stress values.

Stresses	Al Beam	Steel Beam	Al cylinder	Steel cylinder
Max	2.13	9.223	4.75	7.17
Min	0.002	0.24	0.08	3.48

Fig. 4(a) Displacement graph of aluminum cantilever beam

Fig. 4(b) Displacement graph of Steel cantilever beam

Fig. 4(c) Displacement graph of Al cylinder

Fig. 4(d) Displacement graph of Steel cylinder

Fig. 4(a), 4(b), 4(c) and 4(d) show the relationship between displacement and time in Al and Steel beam, Al and steel cylinder respectively. The graph implies that displacement is directly proportional with time irrespective of the type of material.

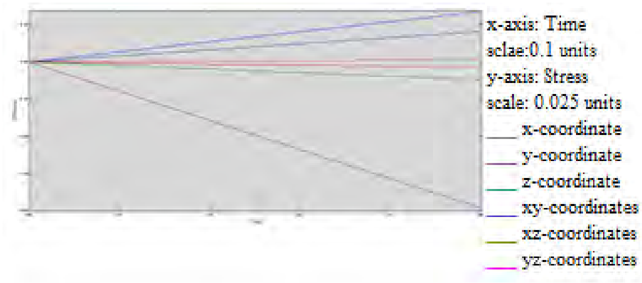

Fig. 5(a) Stresses graph of Al cantilever beam

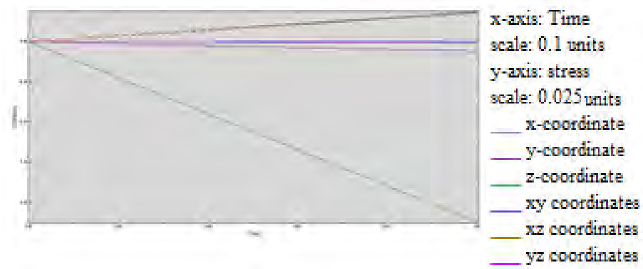

Fig. 5(b) Stresses graph of Steel cantilever beam

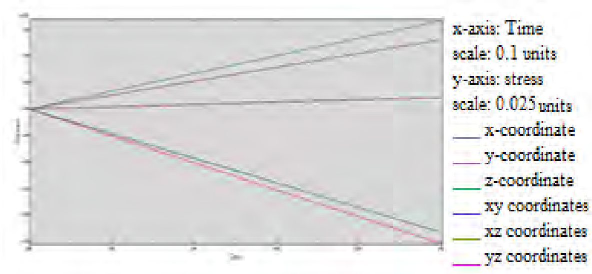

Fig. 5(c) Stresses graph of Al cylinder

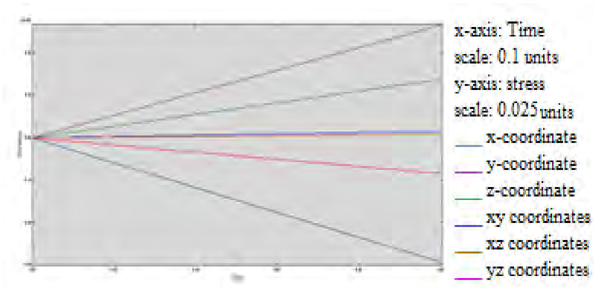

Fig. 5(d) Stresses graph of Steel cylinder

Fig. 5(a), 5(b), 5(c) and 5(d) shows the variation of different stresses acting along x, y , z, xy, yz, xz axis of Al and Steel beam and Al and Steel cylinder respectively.

Table V(a) Stresses values at different time interval of Al cantilever beam

Axis/Time(sec)	0.2	0.6	1
S-xx	0.01	0.05	0.08
S-yy	-0.07	-0.23	-0.39
S-zz	-0.01	-0.03	-0.05
S-xy	0.03	0.08	0.15
S-xz	0	0	0.01
S-yz	0	-0.01	-0.02

Table V(b) Stresses values at different time interval of Steel cantilever beam.

Axis/Time	0.2	0.6	1
s-xx	0.2	0.05	0.1
s-yy	0.01	-0.02	0.03
s-zz	-0.09	-0.27	-0.45
s-xy	0	0	0
s-xz	0.02	0.05	0.1
s-yz	0	0	0

Table V(c) Stresses values at different time interval of Al cylinder.

Axis/Time(sec)	0.2	0.6	1
S-xx	-0.05	-0.15	-0.3
S-yy	-0.07	-0.17	-0.3
S-zz	0.02	0.06	0.13
S-xy	0.01	0.03	0.11
S-xz	0	0	0.01
S-yz	0	0	0.01

Table V(d) stresses values at different time interval of Steel cylinder.

Axis/Time (sec)	0.2	0.6	1
S-xx	-0.02	-0.3	-0.08
S-yy	-0.06	-0.15	-0.29
S-zz	0.05	0.15	0.3
S-xy	0.02	0.05	0.14
S-xz	0	0.01	0.02
S-yz	0	0	0.01

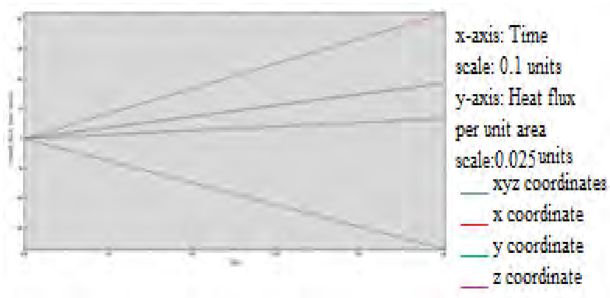

Fig. 6(a) Heat flux graph of Al cylinder

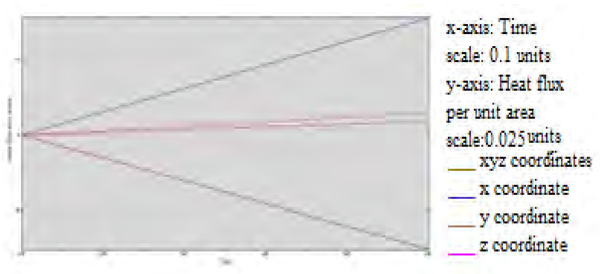

Fig. 6(b) Heat flux graph of Steel cylinder

Fig. 6(a) and 6(b) shows the heat flux per unit area of Aluminum and Steel cylinder.

4. CONCLUSION

The results shows that the stresses are much higher in steel structures as compared to the structures of aluminum, whereas displacement with respect to time is not affected by the type of material used. The heat flux per unit area is greater in aluminum structures as compared to steel structures. With the use of software, it becomes easy to analyze the materials in different conditions without undergoing rigorous mechanical testing. Hence it is concluded that the software testing of materials can be an alternative to hardware testing. However for exact results, the results obtained can be verified by mechanical and thermal testing therefore it is recommended test materials with ABAQUS before implementation for engineering applications.

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