Journal of Mines, Metals and Fuels, *73(3): 751-758; 2025. DOI: 10.18311/jmmf/2025/47424*

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

**Contents available at:** *www.informaticsjournals.co.in/index.php/jmmf*

# Analysis of Lifting Eye Bolt for Different Materials and Cross Sections

**Omkar Dhage, Pravin R. Kale, Arman Ahmad, Chandrakant Jogdand and Ajay D. Pingale***

*Department of Mechanical Engineering, Pimpri Chinchwad College of Engineering, Pune - 411044, Maharashtra, India; ajay9028@gmail.com*

## Abstract

*This study examines the performance of lifting eye bolts with varied geometries and engineering material compositions. The aim of the study is to examine the lifting eye bolt's deformation levels and maximum and minimum stress conditions when subjected to a 500 kg load. A 3D model of the lifting eye bolt is generated using Creo software. Ansys Workbench is utilized to perform Finite Element Analysis (FEA) in order to assess the stresses, deformations, and cross-sections in various materials and geometries. The SS304 eye bolts configured in a ring cross-section show an equivalent Von Mises stress of 56.12 MPa, while the trapezoidal cross-section reduces this stress to 42.69 MPa. This 23.9 % reduction indicates improved load distribution and enhanced structural integrity. Based on the findings, it is evident that the trapezoidal cross-section of the eye bolt consistently exhibits reduced stress and deformation in comparison to the ring cross-section of the eye bolt. This suggests that the trapezoidal shape of the eye bolt is preferable for lifting eye bolts to maximize safety and efficiency.*

***Major Findings:*** *The trapezoidal cross-section had lowered von Mises stress and total deformation than the ring design, indicating better load distribution and structural integrity. SS304 was reliable in high-strength applications, Aluminium Alloy (6061) reduced weight, and IS 2062 was ideal for structural efficiency due to its high strength and low deformation.*

**Keywords:** Ansys Workbench, Deformation, Different Materials, Lifting Eye Bolt, Stress Condition

## 1.0 Introduction

Lifting eye bolts are vital components in a wide range of industries, serving a critical function in the secure suspension and lifting of heavy loads[1–3]. Nowadays the lifting eye bolt is commonly used to lift heavy weight using a chain or belt e.g. construction foundation, electrical control panels, transformers, and toeing arrangements in vehicles that carry high loads with a single point of connection[4–7] The lifting eye bolt has small contact over the eye which carries the whole load. Typically utilized for industrial reasons, the eye bolt is a very important component. Eyebolt plays a major role in protecting the laden crane. The rate of forging of eye bolts is increasing in tandem with increasing industrialization. The performance of these bolts relies on various factors, such as the material composition and the cross-sectional geometry[8,9]. It is essential to conduct a thorough analysis of lifting eye bolts, taking into account various materials and cross-sections, in order to guarantee the secure and dependable functioning of lifting systems. An important factor to take into account is the contact stress that occurs when the lifting pin comes into contact with the clevis-type geometry of the eye bolt. The material properties such as tensile strength, corrosion resistance, and fatigue life play a crucial role. Various studies have investigated the utilization of materials such as stainless steel, alloy steel, and exotic materials under various environmental conditions[10,11]. Ensuring the overall integrity of the lifting system requires proper design and analysis of contact

*Author for correspondence

stresses to prevent premature failure. Eye bolts are available in multiple configurations, including ring, trapezoidal, and shoulder types, each providing distinct advantages in load distribution and strength. The trapezoidal eye bolt has been shown to diminish stress concentrations relative to the conventional ring design, resulting in enhanced force transfer efficiency[12,13]. Commonly utilized materials comprise SS304 stainless steel, recognized for its corrosion resistance and elevated yield strength, carbon steel for robust applications, and alloy steels for enhanced strength in extreme environments. Research indicates that materials such as titanium alloys and high-performance polymers are gaining importance for specialized applications[14–16].

Prior studies have emphasized the importance of bolt strength and preload in determining the bolt's capacity to endure different external loading conditions[17]. Furthermore, previous research has indicated that altering the anchor point or decreasing the slenderness ratio can effectively restrict the shear resistance of clip-angle bolted connections[18]. When developing lifting eye bolts, it is crucial to carefully consider the design of the bolt head to achieve the best balance between material usage, joint strength, and mechanical characteristics[19]. The ASME BTH-1-2005 standard offers design and analysis criteria for vessel lifting lugs, which can be applied to lifting eye bolts[20]. The novelty of this study lies in its detailed comparison of lifting eye bolts with different geometries and material compositions, focusing on their deformation and stress conditions under a 500 kg load. The present research aims introduces the innovative use of the trapezoidal cross-section, which consistently shows reduced stress and deformation, offering a safer and more efficient alternative to the conventional ring cross-section.

In this study, the performance of various materials (SS304, Aluminum Alloy (6061), and IS 2062) and eye cross-sections (ring and trapezoidal) of M16 eye bolts under a 500 kg load was evaluated in detail. Our analysis primary objects to determine which combination of material and design provides the best performance. The performance of several materials and eye cross-sections of M16 eye bolts under a 500 kg load were compared using yield strength, equivalent von Mises stress, total deformation, and weight as important parameters.

## 2.0 Methodology

The methodology plays a vital role in research and analysis, ensuring the smooth execution of the project and the achievement of anticipated outcomes. This framework provides a comprehensive approach that includes project

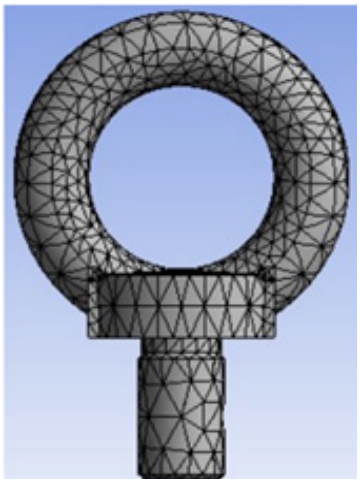


**Figure 1.** Mesh model of eye bolt.

**Table 1.** Material properties

| Sr. No. | Material | Density (Kg/m$^3$) | Y.S. (MPa) | UTS (MPa) | Young's Modulus (GPa) | Poisson's Ratio |
|---|---|---|---|---|---|---|
| 1 | SS304 | 8000 | 205 | 515 | 185 | 0.27 |
| 2 | Aluminium alloy 6061 | 2713 | 259.2 | 313.1 | 69.04 | 0.33 |
| 3 | IS 2062 | 7850 | 250 | 460 | 200 | 0.30 |

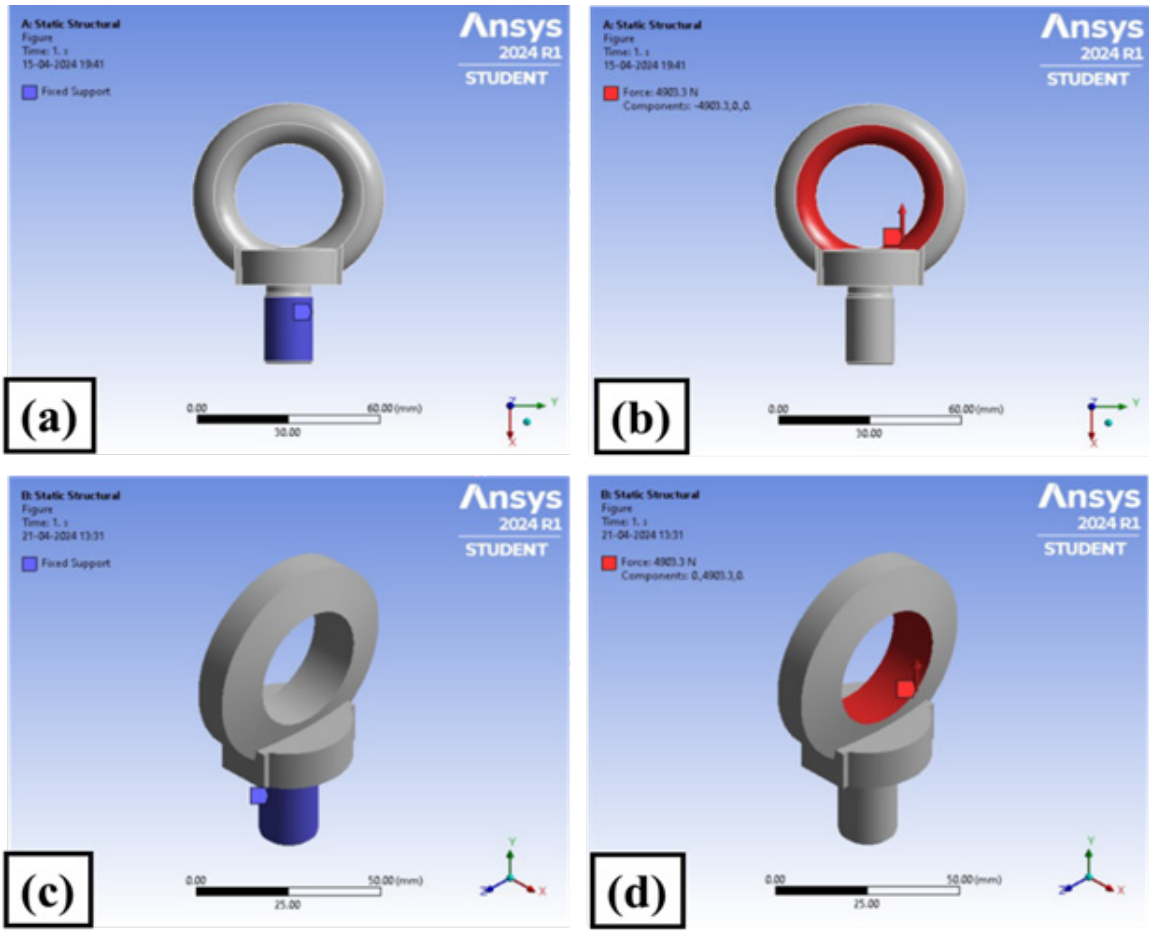



**Figure 2.** Boundary conditions for eye bolt **(a-b)** Ring cross section and **(c-d)** Trapezoidal cross section.

objectives, systematic methods for obtaining precise results, and the evaluation tools utilized. A well-structured methodology is crucial for providing a clear overview of the project and facilitating the achievement of the desired outcomes. The 3D geometry and drawings of the lifting eye bolt are generated using Creo Parametric, a powerful software for creating precise and detailed designs. The selection of materials is determined by various factors such as the specific requirements of the application, the conditions under which the materials will be subjected to load, thermal considerations, dynamic factors, and other relevant considerations. For this case study, we have chosen three materials from the Ansys engineering data: SS 304, Aluminium alloy wrought 6061 and IS 2062.

Following the selection of materials, the geometry is imported from an external 3D modelling software and then refined to align with the Ansys boundary conditions. The boundary conditions employed for the eye bolt are shown in Figure 2(a-d). Accurate results are heavily influenced by the meshing process, which relies on the number of nodes and elements within the mesh. The mesh utilized (Figure 1) in this study consists of tetrahedron elements, comprising a total of 4379 elements and 7911 nodes. The importance of meshing in FEM analysis is second only to geometry creation. After generating the mesh, the threaded bolt side is securely fixed, and a tensile load of 5000 N is applied to the round cross-section. The findings offer valuable insights into the distribution of stress and the characteristics of deformation under specific loading conditions. The properties of various materials used for eye bolts is listed in Table 1.

## 3.0 Results and Discussion

A number of variables, including yield strength, equivalent von Mises stress, total deformation, and weight, must be

**Table 2.** Properties of eye bolt under a loading of 500 kg

| Sr. No. | Material | Eye cross section | Eye Bolt Size | Yield Strength (MPa) | Equivalent Von Mises Stress (MPa) | Total Deformation (mm) | Eye Bolt Weight (Kg) |
|---|---|---|---|---|---|---|---|
| 1 | SS304 | Ring | M16 | 205 | 56.12 | 0.014 | 0.295 |
| | SS304 | Trapezoidal | M16 | 205 | 42.69 | 0.011 | 0.295 |
| 2 | Aluminum Alloy (6061) | Ring | M16 | 259.2 | 58.51 | 0.039 | 0.099 |
| | Aluminium Alloy (6061) | Trapezoidal | M16 | 259.2 | 39.2 | 0.029 | 0.099 |
| 3 | IS 2062 | Ring | M16 | 250 | 57.45 | 0.013 | 0.287 |
| | IS 2062 | Trapezoidal | M16 | 250 | 39.12 | 0.01 | 0.287 |

taken into account when comparing the performance of various materials and eye cross section of M16 eye bolts under a 500 kg load. The analysis encompasses three different materials: SS304, Aluminium Alloy (6061), and IS 2062. These materials were tested in two different eye cross sections: ring and trapezoidal. The summary of the obtained results is given in Table 2 and discussed in subsequent sections.

## 3.1 SS304 Eye Bolts

Figure 3 depicts the results for the SS304 eye bolt under analysis, highlighting both stress and deformation characteristics for two distinct cross sections. Ring cross-section SS304 eye bots demonstrate a yield strength of 205 MPa. The observed equivalent von Mises stress is 56.12 MPa when configured in a ring cross-section. The stress value observed in this study is significantly lower than the yield strength of the material, suggesting that the material maintains its elasticity even when subjected to the applied load. The recorded total deformation for this configuration is 0.014 mm, indicating a minimal amount of deformation. This observation highlights the high stiffness and low deformability of SS304. The weight of the ring cross-section eye bolt is 0.295 kg.

Regarding the trapezoidal cross-section, it is worth noting that the SS304 eye bolts exhibit a decrease in the equivalent von Mises stress, which amounts to 42.69 MPa. The decrease in value suggests a more even spread of the imposed force, resulting in reduced areas of high stress. As a result, the overall deformation is reduced to 0.011 mm, highlighting the effectiveness of the trapezoidal design in minimizing deformation when subjected to a load. No change in the weight of the eye bolt (0.295 kg) is observed.

## 3.2 Aluminum Alloy (6061) Eye Bolts

Figure 4 depicts the results for the Aluminium Alloy (6061) eye bolt under analysis, highlighting both stress and deformation plots. It was observed that the Aluminium Alloy (6061) eye bolt exhibited a higher yield strength of 259.2 MPa in comparison to SS304. Based on the ring cross-section configuration, the equivalent von Mises stress measures at 58.51 MPa. This value is well below the yield strength, indicating that the material operates safely within the elastic region. Nevertheless, the total deformation for this configuration measures 0.039 mm, surpassing that of SS304. This can be attributed to the lower stiffness of aluminium. The weight of the ring cross-section aluminium eye bolt is significantly reduced, measuring at 0.099 kg.

The equivalent von Mises stress for a trapezoidal cross-section eye bolt is reduced to 39.2 MPa for the aluminium eye bolt. The design successfully reduces stress levels, thereby improving the load-bearing capacity.

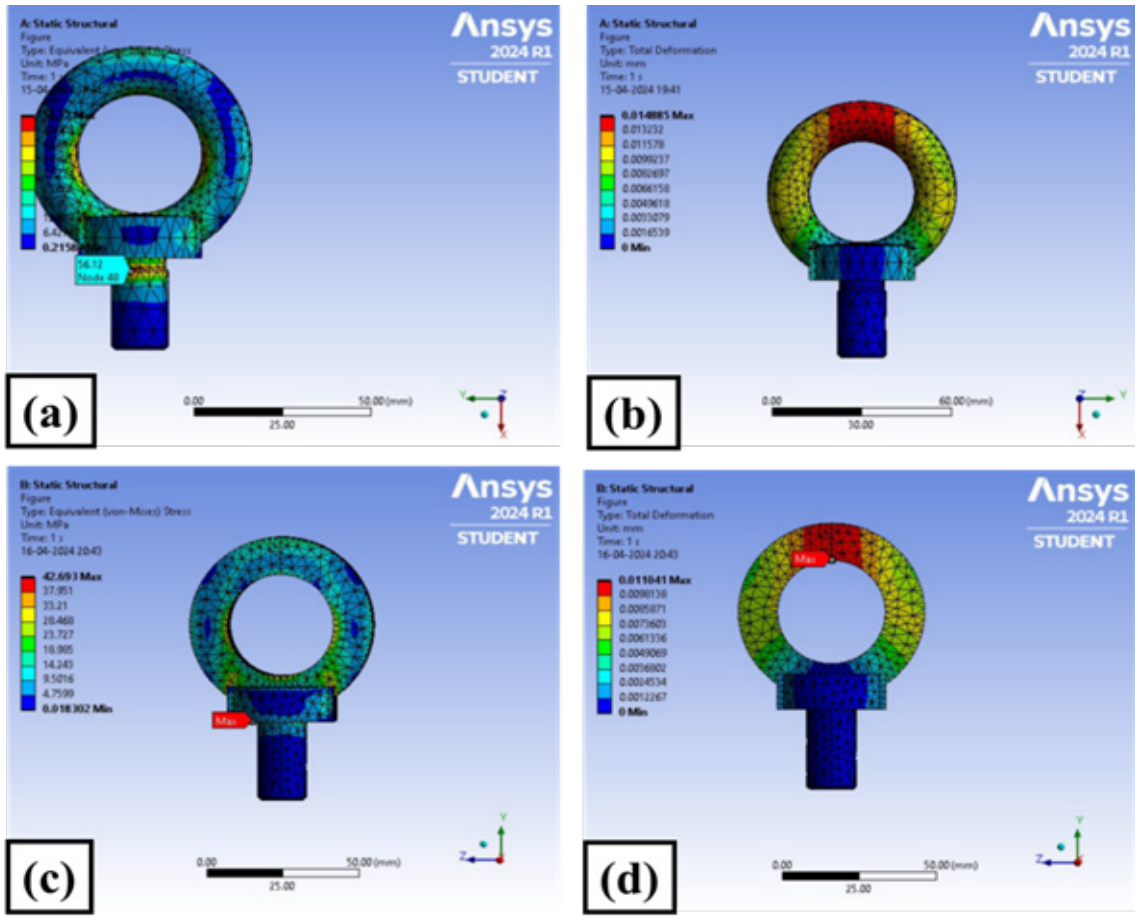



**Figure 3.** Results for SS304 eye bolt **(a)** stress plot for ring cross-section, **(b)** deformation plot for ring cross-section, **(c)** stress plot for trapezoidal cross section and **(d)** deformation plot for the trapezoidal cross-section.

In this configuration, the total deformation measures 0.029 mm, which is still higher than SS304 but has been reduced compared to the ring cross-section. This suggests a performance improvement. The weight remains unchanged at 0.099 kg, highlighting the lightweight nature of the material.

## 3.3 IS 2062 Eye Bolts

Figure 5 presents the results for the IS 2062 eye bolt under analysis, highlighting both stress and deformation characteristics for two distinct cross sections: ring and trapezoidal. Eye bolts in the cross-section of rings made from IS 2062, a type of mild steel, exhibit a yield strength of 250 MPa. The ring cross-section eye bolt of IS 2062 exhibits a von Mises stress of 57.45 MPa, which is comfortably below the elastic limit. The total deformation measures 0.013 mm, which is similar to that observed in SS304. This suggests that the material possesses commendable rigidity and strength. The weight of the ring cross section eye bolt is 0.287 kg.

The IS 2062 trapezoidal cross section eye bolt demonstrates a lower von Mises stress of 39.12 MPa. This indicates that the load distribution is efficient and comparable to other materials with a similar cross section. The total deformation is reduced to 0.01 mm, which is the smallest among the materials tested, highlighting the efficiency of the trapezoidal design. The weight remains constant at 0.287 kg, showcasing that despite the enhanced load distribution and reduced deformation, the trapezoidal design does not incur a significant increase

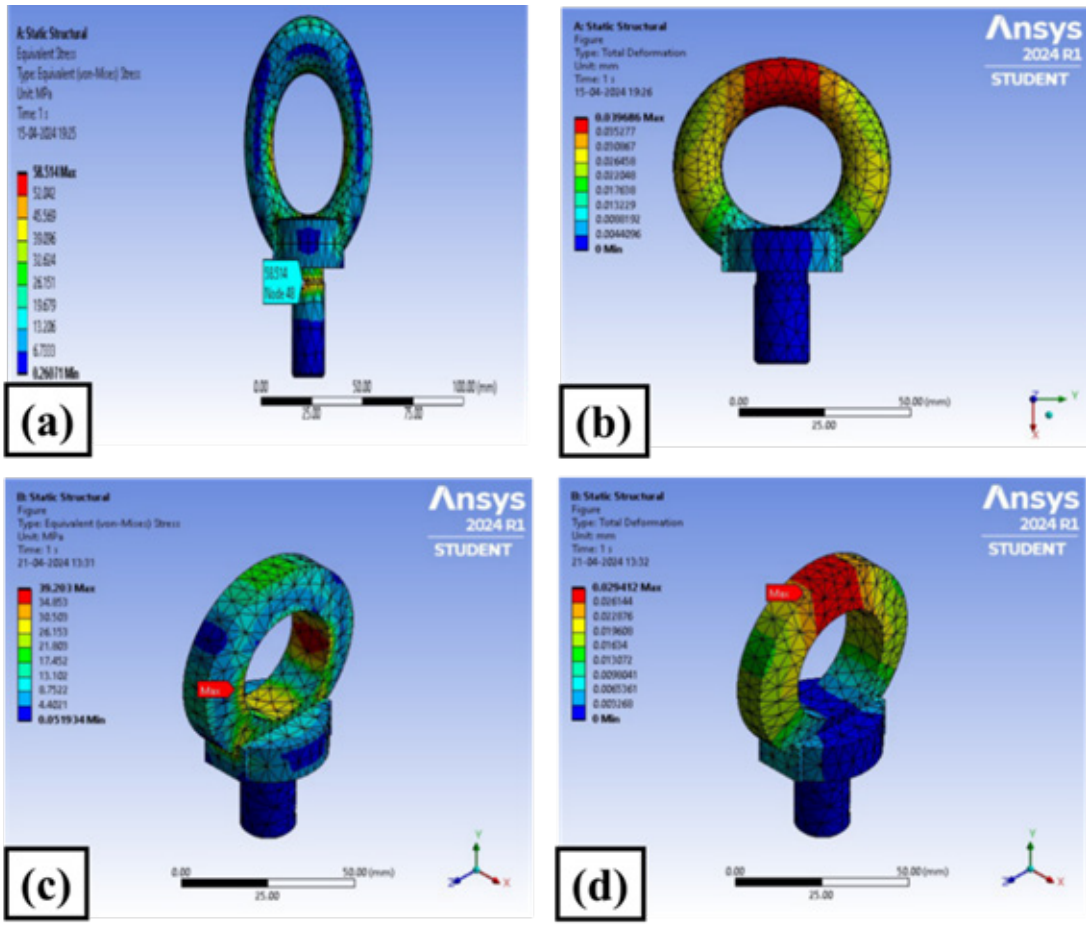



**Figure 4.** Results for Aluminum Alloy (6061) eye bolt **(a)** stress plot for ring cross-section, **(b)** deformation plot for ring cross-section, **(c)** stress plot for trapezoidal cross section and **(d)** deformation plot for trapezoidal cross-section.

in weight, maintaining the balance between strength and weight.

## 4.0 Conclusion

In this paper, the performance of various materials (SS304, Aluminum Alloy (6061), and IS 2062) and eye cross-section (ring and trapezoidal) of M16 eye bolts under a 500 kg load were evaluated in detail. After analyzing the performance of different materials and cross section, it was observed that the trapezoidal design consistently exhibited lower equivalent von Mises stress and total deformation. These findings suggest that the trapezoidal design allows for a more efficient distribution of loads and enhances the overall structural integrity. SS304 exhibits impressive performance in high-strength applications where rigidity is essential, thanks to its low deformation and reasonable stress levels. Despite having a lower yield strength compared to Aluminium Alloy (6061) and IS 2062, SS304 proves to be a reliable choice. Aluminium Alloy (6061) exhibits a higher yield strength and is known for its lightweight properties. However, this characteristic may pose a limitation in applications where minimal deformation is required. Nevertheless, the decreased weight of the material proves to be a noteworthy benefit in situations where weight reduction is of utmost importance. The material IS 2062 demonstrates a remarkable combination of high yield strength and minimal deformation, particularly in the trapezoidal configuration. This unique characteristic makes it an ideal choice for applications that demand both strength and structural efficiency. Through rigorous

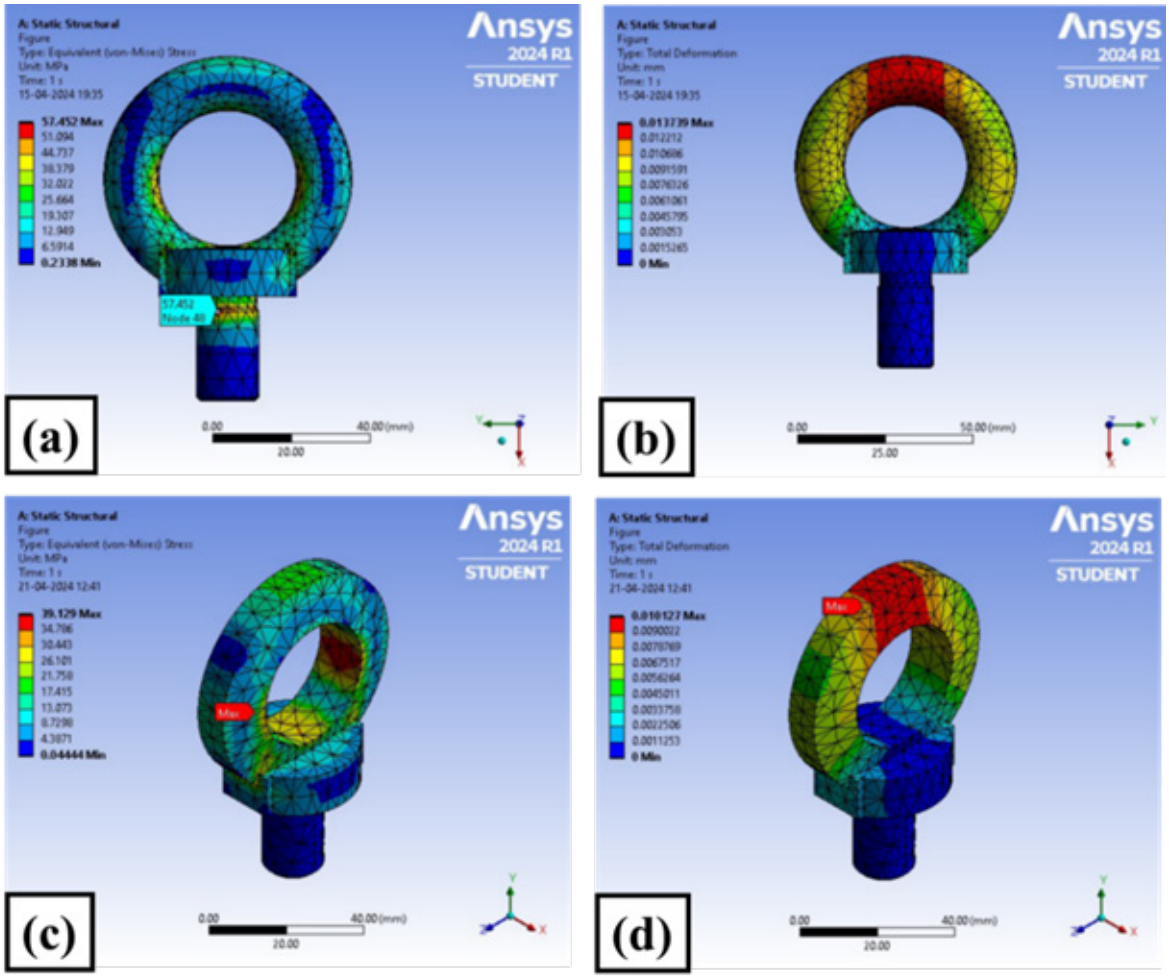



**Figure 5.** Results for IS 2062 eye bolt **(a)** stress plot for ring cross-section, **(b)** deformation plot for ring cross-section, **(c)** stress plot for trapezoidal cross section and **(d)** deformation plot for trapezoidal cross-section.

experimentation and analysis, it has been consistently observed that the trapezoidal design surpasses the ring cross section in effectively minimizing stress and deformation. Additionally, when it comes to rigidity and strength, SS304 and IS 2062 exhibit superior performance in comparison to Aluminium Alloy (6061).

## 5.0 References

1. Antalffy LP, Miller GA III, Kirkpatrick KD, Rajguru A, Zhu Y. The design of lifting attachments for the erection of large diameter and heavy wall pressure vessels. Int J Press Vessel Pip. 2016; 139:12-21. https://doi.org/10.1016/j.ijpvp.2016.02.020
2. Jawwad AKA, AlShabatat N, Mahdi M. The effects of joint design, bolting procedure and load eccentricity on fatigue failure characteristics of high-strength steel bolts. Eng Fail Anal. 2021; 122:105279. https://doi.org/10.1016/j.engfailanal.2021.105279
3. Krishnamurthy N. A fresh look at bolted end-plate behavior and design. Eng J. 1978; 15(2):39-49. https://doi.org/10.62913/engj.v15i2.311
4. Silva Filho HVH, De Oliveira JMAM, Barboza AG, Silva LM, De Melo MT, Barboza DCP, *et al.* Bandpass filter using open loop microstrip resonators for a power substation eyebolt fault detection system. In: 2023 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC).

IEEE; 2023. p. 178-80. https://doi.org/10.1109/IMOC57131.2023.10379730
5. Silva Filho HVH, Santos RGM dos, Barbosa DCP, Melo MT de, Novo LRGSL. Detection of eyebolt faults using a random forest ensemble model based on multiple high-frequency electromagnetic parameters. J Microwaves Optoelectron Electromagn Appl. 2023; 22(3):379-95. https://doi.org/10.1590/2179-10742023v22i3271067
6. Silva Filho HVH, Barbosa DCP, Coutinho MS, De Melo MT, Dos Santos RGM, Llamas-Garro I. Reliable structural failure detection in eye bolts using reflectometry signals. In: 2020 50th European Microwave Conference (EuMC). IEEE; 2021. p. 1107-10. https://doi.org/10.23919/EuMC48046.2021.9338147
7. Silva Filho HVH, Coutinho MS, de Melo MT, de Oliveira EMF, Tarragô VL, Novo LRGSL, *et al*. Design of a connector for fault detection in eye bolts used as insulator anchorages. Eng Res Express. 2020; 2(4):45021. Available from: https://doi.org/10.1088/2631-8695/abc9d0
8. Gough HJ, Cox HL, Sopwith DG. Design of crane hooks and other components of lifting gear. Proc Inst Mech Eng. 1934; 128(1):253-360. Available from: https://doi.org/10.1243/PIME_PROC_1934_128_014_02
9. Dipu MNH, Apu MH, Chowdhury PP. Identification of the effective crane hook's cross-section; 2024. https://doi.org/10.21203/rs.3.rs-3439199/v1
10. Pingale AD, Owhal A, Belgamwar SU, Rathore JS. Co-deposited CuNi@MWCNTs nanocomposites for structural applications: tribo-mechanical and anti-corrosion performances. Trans IMF. 2023; 101(2):93-100. https://doi.org/10.1080/00202967.2022.2127512
11. Pingale AD, Belgamwar SU, Rathore JS. The influence of Graphene Nanoplatelets (GNPs) addition on the microstructure and mechanical properties of Cu-GNPs composites fabricated by electro-co-deposition and powder metallurgy. Mater Today Proc. 2020; 28:2062-7. https://doi.org/10.1016/j.matpr.2020.02.728
12. Lin SF, Zhu ZY. The finite element analysis of a shipyard's lifting eye with load. Adv Mater Res. 2013; 631:1006-10. https://doi.org/10.4028/www.scientific.net/AMR.631-632.1006
13. Saleh SH. Ultimate capacity of pad eyes in lifting operations [dissertation]. Stavanger, Norway: University of Stavanger; 2016.
14. Majumder B, Pingale A, Katarkar A, Belgamwar S, Bhaumik S. Developing Al@GNPs composite coating for pool boiling applications by combining mechanical milling, screen printing and sintering methods. Adv Mater Process Technol. 2022; 08:1-12. https://doi.org/10.1080/2374068X.2022.2036037
15. Owhal A, Choudhary M, Pingale AD, Belgamwar SU, Mukherjee S, Rathore JS. Non-cytotoxic zinc/f-graphene nanocomposite for tunable degradation and superior tribo-mechanical properties: Synthesized via modified electro co-deposition route. Mater Today Commun. 2023; 34:105112. Available from: https://doi.org/10.1016/j.mtcomm.2022.105112
16. Pingale AD, Belgamwar SU, Rathore JS. Synthesis and characterization of Cu-Ni/Gr nanocomposite coatings by electro-co-deposition method: Effect of current density. Bull Mater Sci. 2020; 43(1):66. https://doi.org/10.1007/s12034-019-2031-x
17. Smyth AD. Effect of bolt strength and loading conditions on a 7/8" bolt within an end-of-car arrangement. In: IEEE/ASME/ASCE 2008 Joint Rail Conference. ASMEDC; 2008. p. 21-8. https://doi.org/10.1115/JRC2008-63006
18. Natesan V, Madhavan M. Experimental study on beam-to-column clip angle bolted connection. Thin-Walled Struct. 2019; 141:540-53. https://doi.org/10.1016/j.tws.2019.04.048
19. Landt RC. Criteria for evaluating bolt head design. J Eng Ind. 1976; 98(4):1179-82. https://doi.org/10.1115/1.3439078
20. Williams DK. A critical review of ASME BTH-1-2005 in the design and analysis of vessel lifting lugs. Codes and Standards. ASMEDC; 2007. p. 609-17. https://doi.org/10.1115/PVP2007-26071