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Analysis of Thermal and Mechanical Stresses on Cargo Shipments Comparison of AH36 and of Q235B Using ANSYS

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Abstract

This study determines a meticulous study of thermal and machinelike stresses on baggage shipments by utilizing ANSYS, attracting on AH36 and on Q235B—two materials usually secondhand on unrefined petroleum ship construction. The research checks stress disposal, deformity, and strain under warm and mechanical stowing. Findings display that AH36 has better opposition to thermal stresses created by hotness alternatives 'tween seawater and unrefined petroleum but happenings a larger maximum Von Mises stress (1574.3 MPa) than Q235B (1428.7 MPa) under warm loading unique. When two together warm and machinelike loads are employed, the maximum Von Mises stress rises significantly, arriving at 2159.5 MPa for AH36 and 1958.4 MPa for Q235B. Furthermore, Q235B exhibits marginally lower deformity, adaptable strain, and shear adaptable strain distinguished to AH36, though these principles increase under linked loading. Despite these distinct nesses, Q235B remains a reasonable alternative for less demanding shipment uses, while AH36 offers better depiction on extreme environments. These insights are essential for selecting appropriate fabrics on unrefined petroleum products engaged on a hostile encounter design to guarantee structural uprightness and dependability under variable functional conditions.

Keywords: Stress of thermal, stress of mechanical, software of ANSYS, AH36, Q235B, tanker of crude oil, stress of von Mises, deformation, strain, shear, and flexible strain

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تحليل الضغوط الحرارية والميكانيكية في شحنات البضائع مقارنة بين AH36 و Q235B باستخدام ANSYS

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المستخلص

تُجري هذه الدراسة دراسةً دقيقةً للإجهادات الحرارية والآلية في شحنات الأمتعة باستخدام برنامج ANSYS، مُركزةً على AH36 وQ235B - وهما مادتان تُستخدمان عادةً في بناء سفن البترول الخام. يفحص البحث التخلص من الإجهاد، والتشوه، والانفعال تحت التخزين الحراري والميكانيكي. تُظهر النتائج أن AH36 يتمتع بمقاومة أفضل للإجهادات الحرارية الناتجة عن بدائل الحرارة بين مياه البحر والنفط الخام، ولكنه يُعاني من إجهاد فون ميزس أقصى (1574.3 ميجا باسكال) أعلى من Q235B (1428.7 ميجا باسكال) تحت التحميل الحراري فقط. عند استخدام حمولتين حراريتين وآليتين معًا، يرتفع إجهاد فون ميزس الأقصى بشكل ملحوظ، ليصل إلى 2159.5 ميجا باسكال لـ AH36 و1958.4 ميجا باسكال لـ Q235B. علاوة على ذلك، يُظهر Q235B تشوهًا أقل، وإجهادًا قابلًا للتكيف، وإجهادًا قابلًا للتكيف مع القص، مقارنةً بـ AH36، على الرغم من أن هذه الخصائص تزداد تحت الأحمال المرتبطة. على الرغم من هذه الاختلافات، يظل Q235B خيارًا مناسبًا للاستخدامات الأقل تطلبًا للشحن، بينما يُقدم AH36 أداءً أفضل في البيئات القاسية. تُعد هذه المعلومات أساسية لاختيار الأقمشة المناسبة للمنتجات البترولية الخام التي تُستخدم في تصميمات مواجهة قاسية، لضمان استقامة الهيكل وموثوقيته في ظل ظروف تشغيلية متغيرة.

الكلمات المفتاحية: لإجهادات الحرارية، الإجهادات الميكانيكية، برامج ANSYS، AH36، Q235B، ناقلة النفط الخام، إجهادات فون ميزس، التشوه، الانفعال، القص، والانفعال المرن

انتساب الباحثين

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معلومات البحث

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Introduction

Meanwhile their substantial possessions evenly vary through the density, functionally sorted fabrics play an important role on embellishing the machinelike and warm accomplishment of structures. To comprehend their nature under unexpected temperature changes, analysing temporary warm stresses was essential. Numerical models can efficiently resolve heat and stress equations by permitting an exact three-spatial study of thermal stress classification. Findings display that the material possessions gradient reduces peak stresses, reinforcing the plates' fighting to warm deformations and reconstructing their performance on requests accompanying variable warm loads. Additionally, stress analysis was lively for understanding the answer of functionally sorted plate's to mechanical and warm loads, as the step-by-step change on material possessions across the density directly influences stress classification. Advanced by examining models, which give reason for transverse strain and deformations, support a more correct indicator of plate behaviour, aiding on the incident of revamped fundamental designs for complex machinelike and thermal environments. Furthermore, research on this place field surveys the influence of welding methods on heat disposal, leftover stresses, and material deformation through three-spatial fixed ingredient simulations. The study aims to identify leftover strains and deformities generated by thermal alternatives while connecting and to evaluate how connecting designs influence heat allocation within the material. Results display that hotness allocation significantly influences leftover stresses and deformations, donating to upgraded by binding techniques and underrating unacceptable falsifications on silvery structures.

Literature Review

Hechtman et al. [1] Tested warm stresses on transport structures made by hotness differences, by telling that unequal thermal growth leads to stress concentrations and to potential fundamental disappointment. He emphasized the need to consider thermal stresses in material selection and design to enhance ship safety and durability. Ossowski et al. [2] studied thermal stresses in tankers carrying hot cargo oil, highlighting the risks of deformation or failure and stressing the importance of addressing these stresses in design and operation to improve safety and longevity. Saunders et al. [3] analyzed heat losses in oil tankers, underscoring the significance of cargo heat retention for maintaining temperature stability, improving efficiency, and reducing fuel consumption. Shama et al. [4] investigated shear forces in bulk carriers under shear-induced loading, demonstrating that shear stresses impact structural integrity, especially in high-force areas, and emphasizing the need for stronger structural designs. Aider J. Abid et al.[5],[6] and Shakir et al.[7]–[14] conducted research on heat exchanger projects. Several studies have utilized numerical analyses and predictive models to investigate fluid heat transfer behavior in heat sink geometries, focusing on the effects of the heat transfer coefficient.Fletcher et al. [15] examined thermal stresses in low-alloy steel plates during rapid cooling, showing that quenching generates significant thermal stresses and that optimizing quenching processes is essential for preventing structural issues. Abbasi et al. [16] explored transformation plasticity's effect on thermal stresses during quenching, revealing that phase changes contribute to residual stresses and influence steel's mechanical properties. Guedes Soares et al. [17] investigated nonlinear effects on wave-induced loads in tankers, demonstrating that nonlinearities alter stress distributions and highlighting the need for improved structural design and fatigue analysis in challenging marine environments. Lehmann et al. [18] assessed steel structures' energy absorption during collisions, emphasizing that enhancing steel design improves ship safety and integrity during accidents. Vel and others. [19] Administered a 3-dimensional study of warm stresses on functionally sorted plates, highlighting the role of material composition and temperature distribution in optimizing performance under varying thermal conditions. This project tries warm and mechanical stresses on unrefined petroleum tankers by directing above heats, liquid dynamics, and fundamental completeness. By using leading tools to a degree ANSYS and ABAQUS, the study resolves stress classification and material demeanor, by aiming to embellish person engaged on hostile encounter design and adeptness on extreme operating environments.

Materials and Methods

In this section, we'll cover the matters by working, the processes employed to analyse warm stresses on unrefined petroleum tankers, and the heat situation process by utilising the Ansys 2024 R1 program. Additionally, we'll presented the effects of tests attended at the department of mechanical engineering on the University of Basrah.

Materials

AH36 (High to Strength Steel): A gird grade chiefly exploited on shipbuilding and on marine buildings, acknowledged for allure superior stress and disintegration opposition. It has an low element content and contains items like manganese and silicon that enhance allure substances. Q235B (Low-Strength Carbon Steel): An element gird accompanying low substance, usually secondhand on modern explanation and structural foundations. It offers wonderful formability and weldability but has lower stress opposition distinguished to AH36.

Chemical Properties of Each Metal

- **AH36 Composition:**
  - Carbon (C): 0.18%
  - Manganese (Mn): 0.9%
  - Silicon (Si): 0.1%
  - Phosphorus (P): 0.035%
  - Sulfur (S): ≤ 0.035%
- **Q235B Composition:**
  - Carbon (C): ≤ 0.22%
  - Manganese (Mn): 0.30% - 0.70%
  - Silicon (Si): ≤ 0.30%
  - Phosphorus (P): ≤ 0.045%
  - Sulfur (S): ≤ 0.045%

ANSYS Method 2024 R1 Testing for Marine Structures Analysis

ANSYS 2024 R1 will be handled for mathematical reasoning of marine buildings to determine their reaction to various loads, including stress and to warm belongings. The spreadsheet engages the Finite Element Method (FEM) to pretend material behavior under differing operating environments by helping on design growth and enhancing the security of sea buildings on questioning atmospheres. This analysis will analyses the impact of machinelike and warm loads, chiefly to more precisely conduct evaluations and reconstruct the security and adeptness of ships and sea vessels. Figure (1) depicts the baggage hold model and the standards for judging or deciding secondhand on this report.

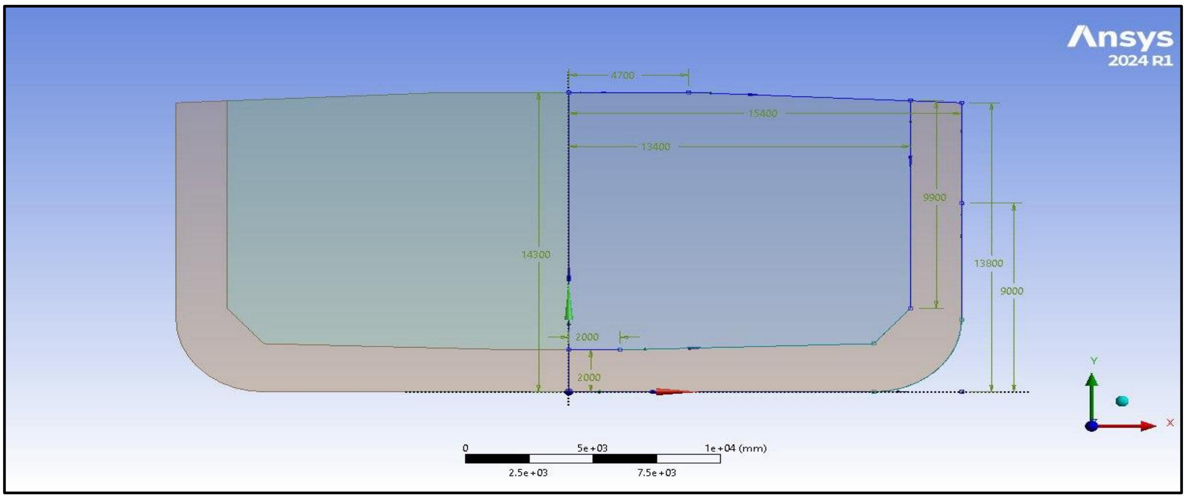

Figure (1): Ship Cargo – The experiment was completed activity by utilizing two types of iron, by accompanying the first being AH36

Heat Treatment

The heat situation was acted on the samples to better their machinelike features. The process contained warming to a named temperature (90°C), understood by abating via normalization by utilizing water at 2°C or air at 5°C, contingent by the hardware type and necessities. The mechanical properties of the materials are presented in as shown in table (1).

Table (1): Mechanical material property

Material	Young's modulus (MPa)	Poisson's ratio	Yield strength (MPa)	Thermal expansion coefficient (1/K)
AH36	206,000	0.3	355	1.2×10^{-5}
Q235B	200,000	0.26	235	1.16×10^{-5}

Heat transfer coefficients can be determined using correlation equations based on Yard's procedures. The thermal properties of the materials at room temperature are provided in as shown in table (2).

Table (2): Thermal material property

	Thermal conductivity (W/K)	Kinematic viscosity (m^2/s)	Prandtl number
AH36	45.3	-	-
Q235B	52.1	-	-
Air	0.0259	1.580×10^{-5}	0.724
Water	0.5610	8.012×10^{-7}	13.44
Oil	0.1068	1.787×10^{-6}	6.229

Result and discussion

Analysis of Mechanical Simulation Results in Cargo Using ANSYS

This study analyzes the mechanical simulation results for cargo shipments using ANSYS, focusing on two metal types: AH36 and Q235B. The results include key mechanical parameters such as Von Mises thermal stress, which evaluates stress from thermal effects and combined forces; deformation, indicating dimensional changes due to applied forces; strain, representing material response to loads; shear elastic strain, caused by shear forces; and normal elastic strain, resulting from perpendicular forces. The study compares the performance of AH36 and Q235B under varying conditions to assess their suitability for metal cargo applications. The results are summarized as shown in Table (3).

Table (3) Metal cargo applications

	One cargo	Stress(Mpa)	Total Deformation(mine)	Elastic Strain(mm/mm)	Shear Elastic Strain(mm/mm)	Normal Elastic Strain(mm/mm)
One cargo	AH36	1574.3	8.3577	0.007156	0.0052211	0.0034339
	Q235B	1428.7	8.3304	0.0071435	0.0051806	0.003411
Tow Cargo	AH36	2159.5	10.772	0.0098158	0.0071336	0.001065
	Q235B	1958.4	10.772	0.0097922	0.0070739	0.001002

The stresses causing material deformation can be assessed using Von Mises stress intensity. From the figures below, it was determined that the stress on the tank is influenced by temperature gradients and boundary conditions. Finite element analysis was conducted for two scenarios (one cargo and two cargo) using two materials, AH36 and Q235B. The maximum Von Mises stress for each loading case is summarized in Table (3). These results were derived through comprehensive finite element analysis. When only thermal loading is applied, the maximum Von Mises stress for Q235B (1428.7 MPa) is lower than that of AH36 (1574.3 MPa) for a single cargo, due to thermal stresses resulting from the temperature difference between the sea and crude oil. Additionally, Q235B exhibits slightly lower deformation, elastic strain, and shear elastic strain compared to AH36.Under combined loading for two cargo, the maximum Von Mises stress increases compared to the single cargo scenario. The maximum stress values recorded are 2159.5 MPa for AH36 and 1958.4 MPa for Q235B. Similarly, deformation, elastic strain, and shear elastic strain for Q235B are slightly lower than AH36 but higher than in the single cargo case. Figures (2, 3, 4 and 5) provide detailed ANSYS results for both one-cargo and two-cargo scenarios.

Mechanical Simulation Results of AH36 for One Cargo

Figure (2), can be realized the AH36 Material Properties: Stress: 1574.3 MPa .Refers to the force exerted per unit area due to loading, influenced by temperature. As temperature increases, thermal expansion reduces the material's resistance, causing an uneven stress distribution. Total Deformation: 8.3577 mm represents the overall shape change caused by both load and heat. Thermal expansion increases atomic movement, leading to a slight rise in deformation compared to normal conditions. Elastic Strain: 0.007156 mm/mm. Indicates the relative length change within the elastic range. Heat reduces the material’s stiffness, making elastic deformation more noticeable and slightly affecting the yield point. Shear Elastic Strain: 0.0052211 mm/mm.Describes deformation due to shear stress. Thermal effects may redistribute shear forces, increasing internal slippage between metal layers. Normal Elastic Strain: 0.0034339 mm/mm .Represents elongation in the load direction. Higher temperatures enhance atomic movement, leading to a slight increase in strain due to additional thermal expansion. as shown in Figure (2).

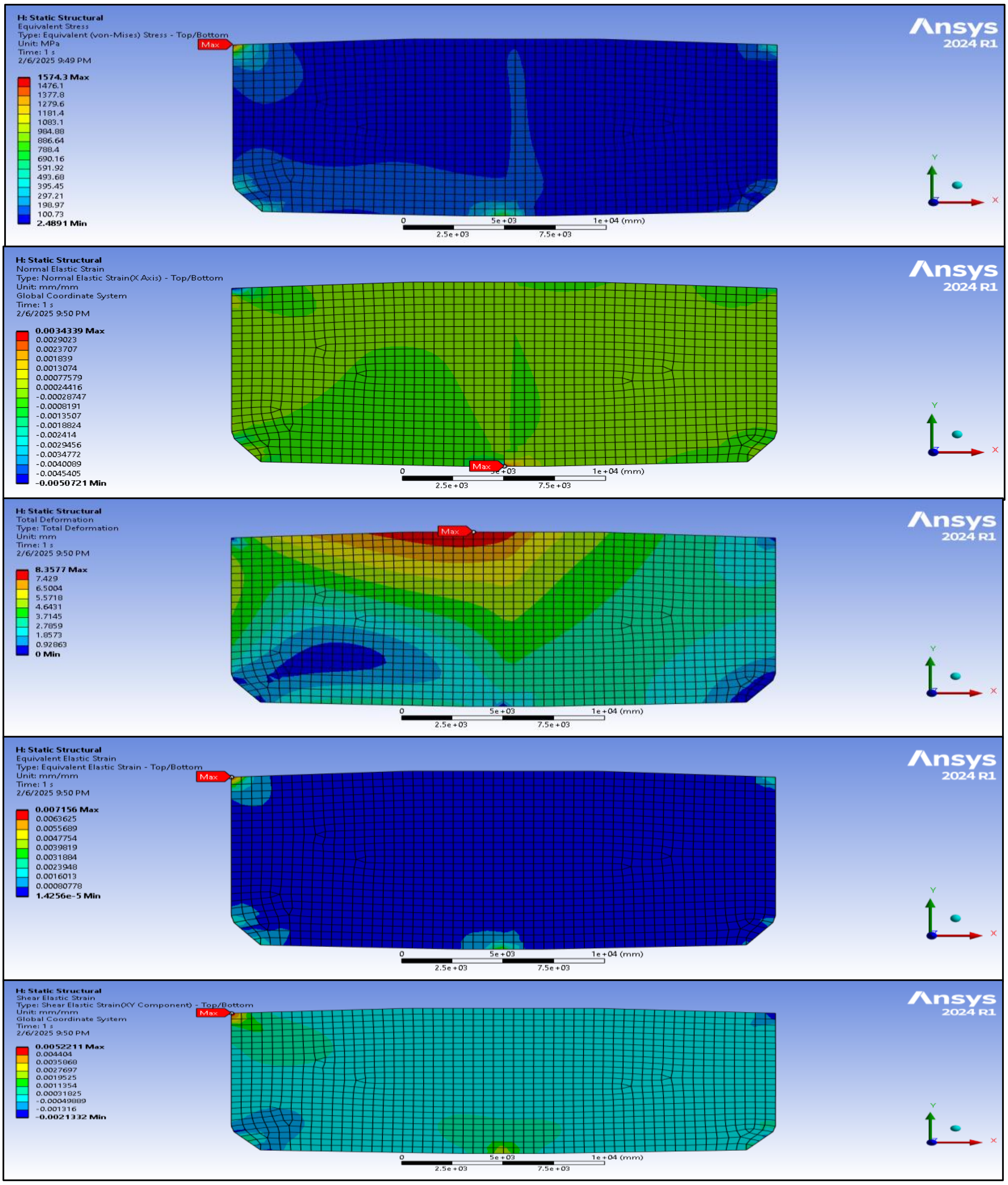

Figure (2): One Cargo AH36 Material

Mechanical Simulation Results of AH36 for Two Cargo

Figure (3), can be presented of Stress: 2159.5 MPa. Increases with higher load and heat, though thermal stresses can weaken the material's resistance. Total Deformation: 10.772 mm.Greater than at room temperature due to thermal expansion caused by temperature variations. Elastic Strain: 0.0098158 mm/mm.Rises at elevated temperatures as the metal becomes more prone to elastic deformation due to reduced resistance. Shear Elastic Strain: 0.0071336 mm/mm.Thermal stresses create internal tension, intensifying shear stress effects. Normal Elastic Strain: 0.001065 mm/mm, increased heat and load cause additional elongation in the normal direction, slightly raising this value. as shown in Figure (3).

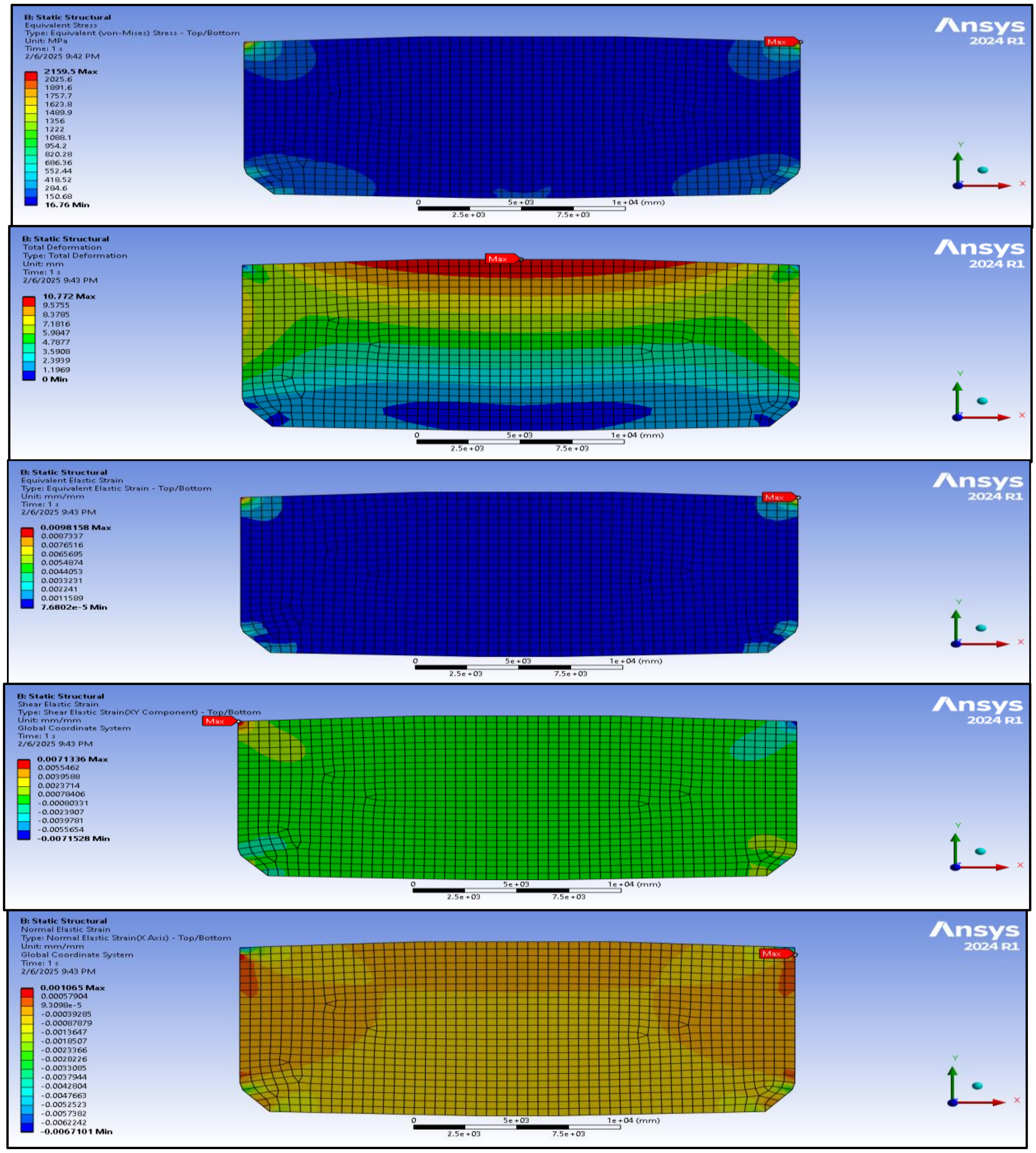

Figure (3): Two Cargo AH36 Material

Mechanical Simulation Results of Q235B for One Cargo

Figure (4), can be shown the material experiences a stress of 1428.7 MPa. Elevated temperatures reduce its resistance to loads through thermal expansion, resulting in decreased rigidity. The total deformation is 8.3304 mm. As temperature rises, the distribution of internal stress changes, potentially increasing deformation compared to standard conditions. Elastic strain measures 0.007143 mm/mm under heat, indicating potential decreased yield point and altered load behavior compared to lower temperatures. Shear elastic strain of 0.0051806 mm/mm increases slightly due to heat, making the material more susceptible to shear stresses through internal force redistribution. Normal elastic strain of 0.003411 mm/mm increases marginally due to thermal expansion, causing slight expansion in the direction of the applied load. as shown in Figure (4)

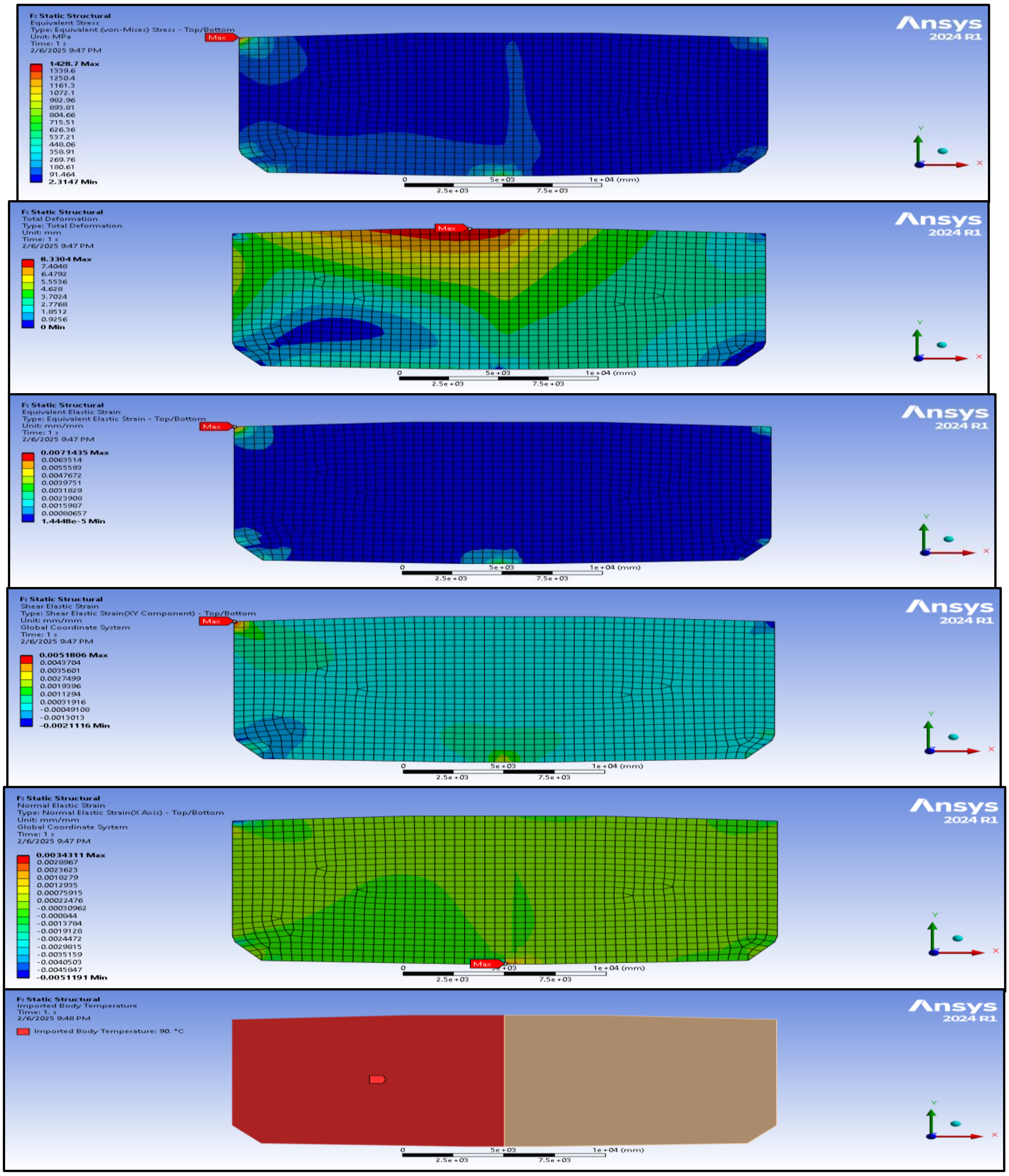

Figure (4): One Cargo Q235B Material

Mechanical Simulation Results of Q235B for Two Cargo

Figure (5), can be seen Stress: 1958.4 MPa This value rises with increasing load. However, thermal expansion can redistribute internal stresses, potentially reducing the material's ability to withstand high stresses. Total Deformation: 10.724 mm Heating contributes to a higher deformation rate by causing the metal to expand and creating temperature differences between its internal and external surfaces. Elastic Strain: 0.0097922 mm/mm at elevated temperatures, this strain increases due to the material's decreased resistance to applied stresses. Shear Elastic Strain: 0.0070739 mm/mm Thermal expansion causes internal forces within the material to redistribute, resulting in a more pronounced response to shear stresses. Normal Elastic Strain: 0.001002 mm/mm. as shown in Figure (5).

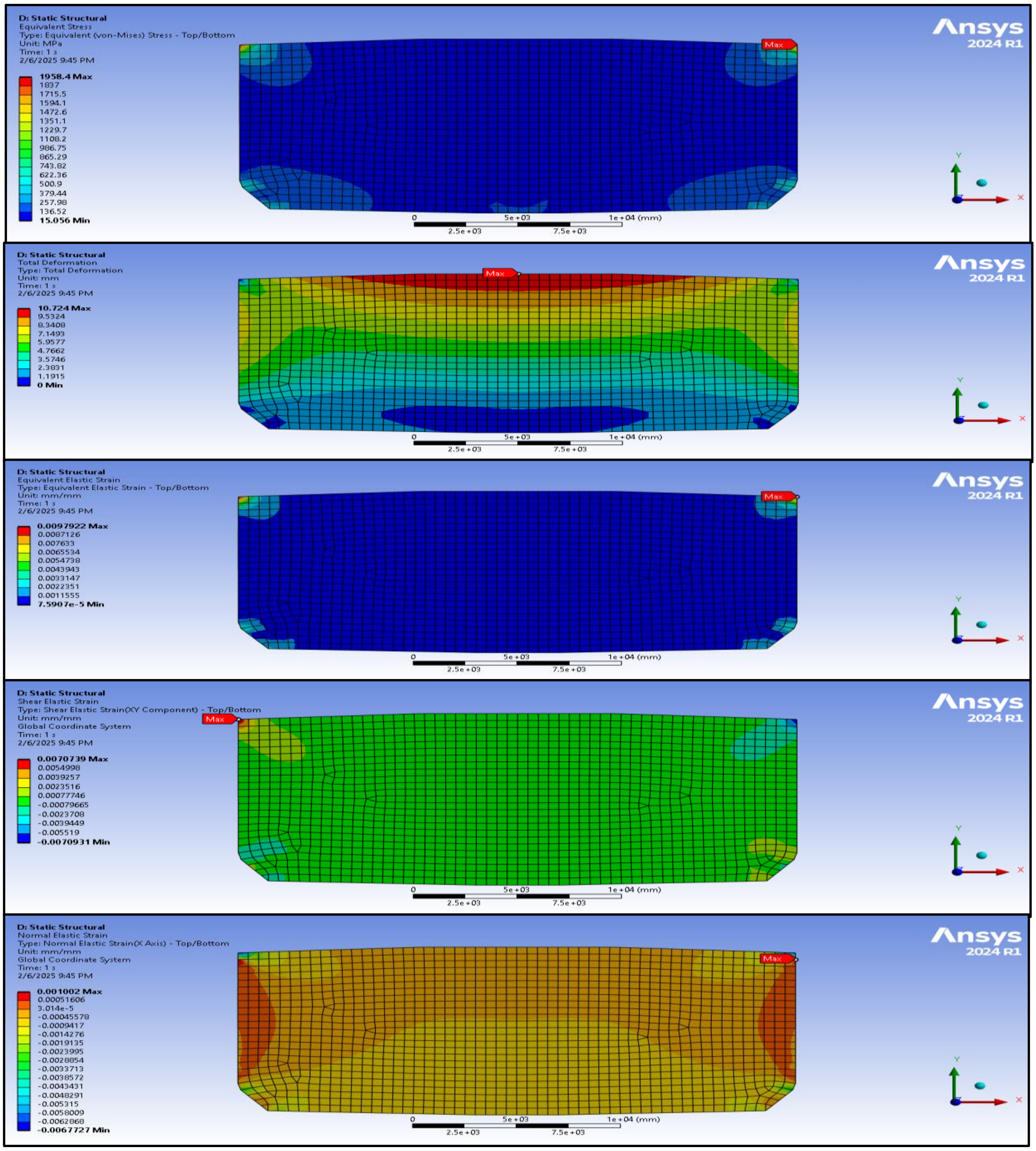

Figure (5) :Two Cargo Q235B Material

Conclusions& Recommendations

The mechanical simulation analysis of cargo shipments using ANSYS provided valuable insights into the performance of AH36 and Q235B metals under different loading conditions. The evaluation considered Von Mises stress, deformation, strain, shear elastic strain, and normal elastic strain. By warm stowing, AH36 exhibited taller stress and strain than Q235B, displaying its better fighting to thermal stress. So, when unprotected to connect thermal and machinelike stowing, both matters knowledgeable raised stress and deformation by accompanying AH36 usually by demonstrating superior act, specifically at terms of maximum Von Mises stress. Overall, AH36 was more acceptable for uses requiring extreme opposition to thermal and machinelike loads.AH36 is urged for requests by involving extreme warm and mechanical loads, to a degree shipbuilding—particularly baggage tanks exposed to extreme hotness variations—due to allure superior ability to endure linked warm and mechanical stresses. Its taller stress fortitude and greater fighting to deformity make it a more responsible choice for fault-finding structural elements. Enhancing boundary condition modeling: Future simulations should incorporate more detailed boundary conditions to better reflect real-world operating environments, ensuring greater accuracy in results.

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