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# Advancing Casing Head Design on Wellhead Equipment Under Hydrostatic Pressure Using Finite Element Analysis

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## ABSTRACT

Ensuring the structural integrity of casing heads under high-pressure conditions is crucial in oil and gas well safety. This study applies Finite Element Analysis (FEA) using Solid-Works 2024 to evaluate a 13-5/8 5K × 13-3/8 5K casing head design under hydrostatic pressure up to 7,500 psi, following API 6A standards. Unlike conventional designs that rely on a single material, this research compares AISI 4130 alloy steel and Stainless Steel 410 to assess their structural performance and interchangeability. The simulation analyzed stress distribution and deformation, revealing both materials stayed well within safe limits, with a maximum Von Mises stress of 18,196 psi and deformation of 0.00006112 inch. The results demonstrate that material substitution is structurally viable, offering a cost-effective and supply-chain-resilient solution. The novelty lies in validating design adequacy through simulation of the weaker material, confirming its suitability for both. This method enhances design flexibility and material selection strategies for pressure-containing components.

**KEYWORDS:** *Finite Element analysis, Casing head, Hydrostatic simulation, AISI 4130, Stainless Steel 410.*

## 1.0 INTRODUCTION

In 2020, the world used or consumed approximately 88.7 million barrels of oil per day [1]. The increasing demand for oil and gas, the number of oil and gas wells to be drilled in 2022 is expected to be 118,500 [2]. In oil and gas exploration, high down hole pressures often exceeding 10,000 psi pose serious challenges to the structural integrity and safety of well components [3].The wellhead is an important component in the context of well integrity and operational safety, as it serves as a link between well and riser in offshore oil wells. Wellheads, combined with the BOP and/or the Christmas tree, act as the final barrier element preventing leakage of oil from the well into the environment. A wellhead system includes components on the surface of an oil or gas well that provide access to the mains bore of the casing or tubing or to the annulus as well as enable pressure control of a production well. The wellhead system serves as the surface termination of a wellbore that incorporates facilities for installing casing hangers during the well construction phase, and also incorporates a means of hanging the production tubing and installing the Christmas tree and surface flow-control facilities in preparation for the production phase of the well [4],[5]. The wellhead system is a critical interface between the surface equipment and the casing strings, where the Casing Head, located at the bottom of the stack, serves as both a structural base and a pressure containment component [6],[7]. It isolates formation pressure and supports the casing and blowout preventer (BOP), preventing uncontrolled fluid flow, known as blowouts [8].

In general, during the process of oil and gas exploration, the locations of oil and gas sources as well as the drilling depth have been calculated in advance. This is done to determine the size and durability of the wellhead according to the criteria of the location to be drilled. The design of a wellhead must meet specific criteria to ensure safety, reliability, and performance under various operational conditions. Key parameters include pressure rating based on the maximum expected surface pressure, typically ranging from 2,000 to 15,000 psi, and temperature rating suited to the environment, following standards like API 6A. Material selection is critical, often requiring corrosion-resistant alloys, especially in sour service environments.

The wellhead must accommodate all load cases, including internal and external pressures, temperature-induced stress, and axial loads. It should support casing and tubing systems, provide reliable primary and secondary sealing mechanisms, and be configured to integrate master valves, wing valves, swab valves, and chokes. Resistance to erosion, corrosion, and mechanical wear is essential, often addressed through specialized materials or coatings. Additionally, the design must comply with international safety standards (such as API 6A and ISO requirements) and allow for operational flexibility to support future interventions or multi-zone completions. Overall, a wellhead must be engineered for durability, easy maintenance, and safe operation throughout the well's lifecycle [9].

During drilling, the wellhead is installed on the surface of the oil and gas well in stages. The main function of the wellhead is to act as the primary structure and protector of the casing strings from the pressure exerted from the bottom of the well to the surface of the oil and gas well. The casing string consists of pipes ranging from 4.5 to 20 inches in diameter, depending on the pressure within the oil and gas well.

The selection and validation of the Casing Head design must consider not only operational loads but also safety factors to accommodate unexpected surges or design uncertainties. A standard design pressure of 5,000 psi is commonly used, with a safety factor of 1.5, resulting in a test pressure of 7,500 psi. Verifying the structural integrity at this pressure is essential to meet API 6A standards [7].

To analyze the structural response of the casing head, this study applies Finite Element Analysis (FEA). FEA enables engineers to simulate real-world load conditions and assess stress distribution, strain concentration, and deformation before physical fabrication [10]. The simulation focuses on a hydrostatic pressure load applied internally to the component. This method can more accurately model the stress and deformation distribution occurring in the casing head. This simulation will provide deeper insights into the wellhead performance in real-world situations, allowing the design to be more precise and tailored to field requirements.

Material selection plays a vital role in the design process. AISI 4130, the low-alloy chromium-molybdenum steel, is widely used in oilfield applications for its high tensile strength and toughness [11]. However, its availability may be limited in certain regions, prompting the need for alternative materials. Stainless Steel (SS) 410, known for its corrosion resistance and wide availability, becomes a potential substitute, although it may differ in mechanical performance under extreme loads [12].

The aim of this study is to simulate the Casing Head under a single pressure condition of 7,500 psi using both AISI 4130 and Stainless Steel 410 materials. The results are used to evaluate structural integrity, identify stress, and support material selection based on strength and safety compliance. This analysis ensures that the design meets operational demands and enhances safety performance.

The novelty of this research lies in the application of a dual-material evaluation strategy for casing head design under hydrostatic pressure. Unlike previous studies that simulate only one material, this research simulates the structurally weaker material (AISI 4130). If AISI 4130 meets the strength and deformation criteria, it can be inferred that SS 410having superior corrosion resistance and mechanical properties will also be acceptable. This approach enables flexibility in material selection based on availability, cost, and corrosion level at the wellhead site. In addition, the study addresses the lack of standard wellhead components in catalogs, highlighting the need for custom design and simulation before manufacturing.

## 2.0 METHOD

### 2.1 Material

Two materials are used for the casing head simulation: AISI 4130 steel and Stainless Steel (SS) 410.The selection of materials for casing heads in wellhead systems must carefully consider mechanical strength, corrosion resistance, weld ability, and compliance with oil and gas industry standards. AISI 4130, the low-alloy steel containing chromium and molybdenum, is a leading choice due to its combination of high tensile strength, excellent toughness at low temperatures, and good weld ability with Post-Weld Heat Treatment (PWHT). These properties make AISI 4130 highly suitable for critical pressure-containing components such as casing heads. On the other hand, SS410, a martensitic stainless steel, offers relatively high mechanical strength after heat treatment and better corrosion resistance compared to plain carbon steels, making it ideal for environments containing carbon dioxide ($CO_2$) or mildly corrosive fluids. Although its mechanical strength is somewhat lower than that of AISI 4130, SS410 provides added corrosion protection, particularly for casing head sections that are more exposed to chemical attack. In many designs, AISI 4130 is used for the main body of the casing head, while SS410 is applied in specific components or as a cladding material to optimize equipment service life, maintain structural integrity, and reduce long-term maintenance costs. From an economic standpoint, the average cost of AISI 4130 is approximately USD 1,800 per ton, while SS 410 typically ranges from USD 2,000–2,400 per ton, depending on regional market and supplier. This price difference reinforces the selection of AISI 4130 as a cost-effective option for standard applications.

However, in environments where corrosion is a major concern, the higher cost of SS 410 may be justified by its superior durability and reduced maintenance requirements. AISI 4130 was chosen for simulation due to its lower yield strength, representing the worst-case scenario. If it passes the design criteria, SS 410, which has higher strength can be assumed to perform equally well. Economically, AISI 4130 is more affordable and widely used. However, SS 410 offers better corrosion resistance, making it more suitable for environments with moderate to high corrosiveness, such as humid, $CO_2$ rich, or mildly acidic conditions. Additionally, AISI 4130's corrosion resistance can be improved using cladding or coating, depending on the application. Simulating only AISI 4130 is a conservative and efficient approach, ensuring both structural reliability and practical feasibility. Further explanation can be found on page 3–4, in the material selection section. Both materials comply with international specifications such as API 6A, ensuring reliable performance in challenging oil and gas operational environments. These materials are selected based on their relevance in the oil and gas industry, where both are commonly used for structural [13].

Table 1 provides a comprehensive comparison of casing head specifications manufactured from AISI 4130 alloy steel and SS 410. Both casing heads are designed according to API 6A standards, featuring top flange sizes of 13-5/8 inches and bottom flange sizes of 13-3/8 inches and rated for a design pressure of 5,000 psi. AISI 4130 exhibits superior mechanical strength, with a tensile strength of 95,000 psi and a yield strength of 75,000 psi under normal conditions, making it highly suitable for high-pressure, high-load applications. In contrast, SS 410 offers a tensile strength of 75,000 psi and achieves slightly higher yield strength of 80,000 psi after appropriate heat treatment, providing a balance between mechanical performance and enhanced corrosion resistance. Both materials maintain a safety factor of 1.5 times the design pressure, in compliance with ASME B31.3 requirements for pressure containing components. This specification comparison highlights the material selection trade-offs between maximizing strength with AISI 4130 and achieving improved corrosion resistance with Stainless Steel 410, depending on specific wellhead service environments and operational priorities[7].

The stainless Steel 410 is preferred in service environments where corrosion resistance is a key consideration, such as in wells exposed to carbon dioxide ($CO_2$) or mildly corrosive fluids. Additionally, SS 410 offers cost advantages and broader availability in regions where AISI 4130 may be scarce. While SS 410 exhibits slightly lower tensile strength, its corrosion resistance and heat-treatable properties make it suitable for less mechanically demanding yet chemically aggressive environments. Table 2 provides a comparative overview of the key selection criteria for AISI 4130 and SS 410, highlighting their respective strengths and optimal application scenarios in wellhead equipment design.

Table1: Casing head specification [7]

| No | Description | Details | |
|---|---|---|---|
| 1 | Casing Head Type | Casing Head: 13-5/8 5K x 13-3/8 5K | Casing Head: 13-5/8 5K x 13-3/8 5K |
| 2 | Top Flange Casing Head (API 6A Standard) | 13-5/8 inch | 13-5/8 inch |
| 3 | Bottom Flange Casing Head (API 6A Standard) | 13-3/8 inch | 13-3/8 inch |
| 4 | Design Pressure (API 6A Standard) | 5000 Psi | 5000 Psi |
| 5 | Material Type | AISI 4130 Alloy Steel | SS 410 |
| 6 | Tensile Strength | 95.000 Psi | 75.000 Psi |
| 7 | Yield Strength | 75.000 Psi (normal temperature) | 80.000 Psi (heat treated) |
| 8 | Safety Factor (ASME B31.3) | 1.5 From Design Pressure (5000 psi) | 1.5 From Design Pressure (5000 psi) |

Table 2: Criteria for AISI 430 and SS 410

| Criteria | AISI 4130 | SS 410 |
|---|---|---|
| Mechanical Strength | Higher | Moderate (but sufficient) |
| Corrosion Resistance | Low (needs coating) | Moderate to good (inherent) |
| Cost | Lower | Slightly Higher |
| Availability | May Vary | Often More Available |
| Best Used Case | High Pressure, Dry Service | Corrosive, Humid, or marine areas |

## 2.2 Design

The hydrostatic test simulation of a 13-5/8 5K x 13-3/8 5K Casing Head was carried out using the Finite Element Analysis (FEA) method to evaluate its ability to withstand high pressure conditions. The first step in the simulation process involves preparing a 3D model of the casing head using SolidWorks software. This stage includes accurate geometric modeling, including flange dimensions and internal profiles, to ensure that the model reflects real conditions. After the geometry is prepared, material properties are assigned. In this case, Stainless Steel is chosen primarily for its excellent corrosion resistance and high yield strength, which makes it a strong candidate as an alternative to AISI 4130, especially when the availability of the latter is constrained. Stainless Steel offers advantages in environments where resistance to rust and corrosion is critical, ensuring durability and long-term performance. However, despite these benefits, Stainless Steel has a lower yield strength compared to SS 410, which may limit its structural applications in certain high-stress environments. As a result, in the research conducted, the hydrostatic test simulation was specifically carried out using only AISI 4130 materials, due to its lower yield strength compared to SS 410. By simulating the test on AISI 4130, if the acceptance criteria are met, it can be assumed that SS 410, which has a higher yield strength, would also pass. Therefore, this study only simulated AISI 4130, representing both materials. This focused approach was necessary to ensure that the simulation results accurately reflect the performance of AISI 4130 under the testing conditions.

## 2.3 Simulation

The design calculations in this study were carried out using the Solid Works application, a 3D solid modeling software that facilitates the creation of parts and assembly drawings through the use of parametric constraints, which define and control the geometry of the model. The step-by-step procedure includes generating the design model, assigning material properties, applying pressure loads, meshing the geometry, performing the simulation analysis, and interpreting the resulting data, as outlined below.

### 2.3.1 Drawing and Modeling

The modeling phase represents the initial stage in developing a prototype, serving as the basis for further simulation and structural evaluation. Figure 1 displays the 3D Solid Works representation of the 13-5/8 5K × 13-3/8 5K casing head, intended for use in performance validation. In Figure 2 shows the dimensions of the casing head.

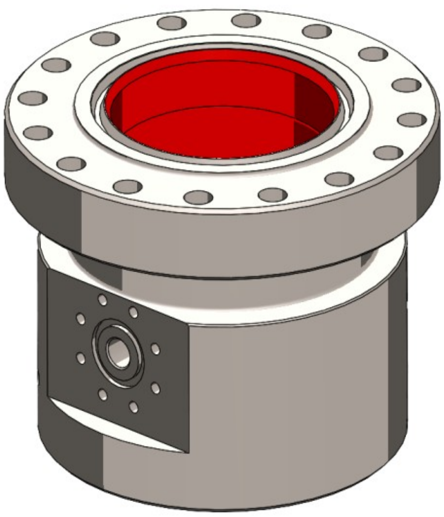

Figure 1: Modeling casing head of 13-5/8 5K X 13-3/8 5K


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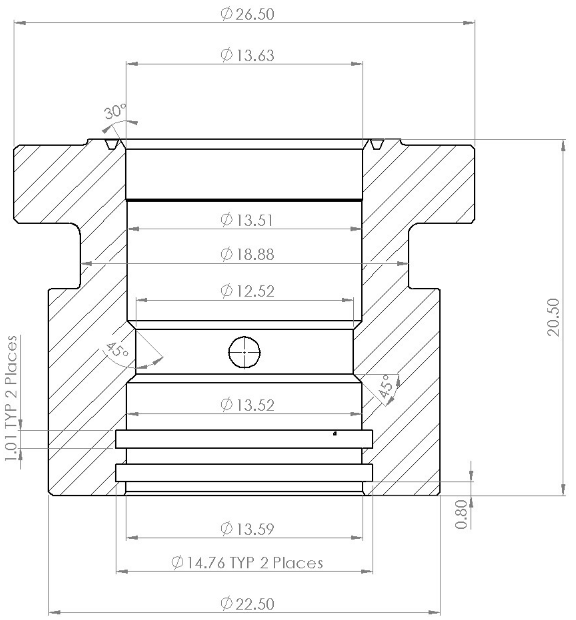


Figure 2: Details casing head 13-5/8 5K X 13-3/8 5K

### 2.3.2 Material Selection

This process is carried out to determine the type of material that will be used and integrated into the model. In this hydrostatic test simulation, AISI 4130, a type of alloy steel is used. The mechanical properties of different casing grades are mentioned in Table 3.

Table 3: Material properties of AISI 4130[11]

| Grade | Yield Strength [psi] | Part Number |
|---|---|---|
| AISI 4130 | 75.000 psi | RND |

### 2.4 Simulation Setup

FEA is a numerical approach used to evaluate engineering designs thoroughly. The process begins with creating a geometric representation of the design. Before running the simulation, it needs to be setting Hydrostatic Shell Test Pressure. The pressure of the casing was modeled according to the API 6A standard. The hydrostatic shell test pressure details are mentioned in Table 4.

Table4: Hydrostatic shell test pressure based on API 6A [7]

| Hydrostatic Shell Test Pressure | | | | | |
|---|---|---|---|---|---|
| Working Pressure Rating | | Nominal size of Flange mm(inch) | | | |
| | | 346 (13-5/8) and smaller | | 346 (13- 3/8) and larger | |
| MPa | (psi) | MPa | (psi) | MPa | (psi) |
| 34.5 | 500 | 51.7 | 7500 | 51.7 | 7500 |

After the pressure values are defined, boundary conditions such as fixation points and applied loads are applied to the model. These settings ensure that the simulation accurately reflects the real conditions experienced by the casing head during operation.

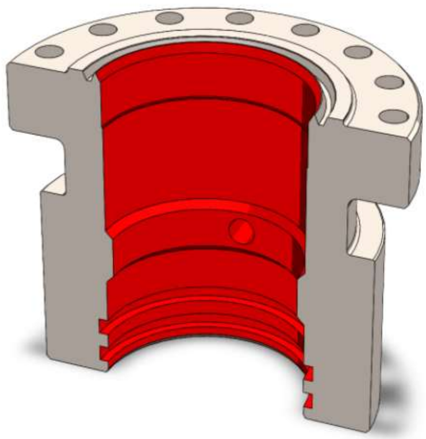

Figure3: The area subjected to pressure (indicated in red)

The region subjected to pressure (indicated in red) was defined prior to meshing. Meshing was applied to discretize the geometry into smaller finite elements. This meshed model is then subjected to analysis to observe stress distribution, displacement, and strain. After the simulation is completed, a report is generated to summarize the results. This report provides a clear assessment of the design's structural integrity and supports decision making for further design modifications if necessary.

## 3.0 RESULT

The simulation performed using Solid Works produced outputs in the form of stress and displacement. Stress distribution and deformation behavior of the casing head were analyzed under material AISI 4130. The hydrostatic pressure applied in the simulation was 7500 psi. Evaluation of the results was conducted based on the acceptance criteria outlined in Table 5.

Table 5: Acceptance criteria simulation for casing head body (AISI 4130) [11]

| Simulation criteria | Acceptance Criteria | Methodology |
|---|---|---|
| Strength | Maximum stress is 67,500 psi (0.9 x material Yield strength hydrostatic test) (API6A x design calculation for pressure containing equipment) | Apply preload 7,500 psi (API6A specification for wellhead equipment) |
| Deformation | Maximum deformation is 1% of the thinnest wall thickness (critical area) which is necking area at 18.88 inches. | American society for metals (ASM)[14] |

### 3.1 Strength

The acceptance criteria for evaluating the structural performance of the casing head under hydrostatic pressure were established based on the API 6A standard for wellhead and Christmas tree equipment. For the AISI 4130 Alloy Steel material, the maximum allowable stress was determined as


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67,500 psi, corresponding to 0.9 times the yield strength specified by API 6A [7],[8]. Meanwhile, for Stainless Steel 410, the acceptance limit was set at 72,000 psi, also following the 90% yield strength rule based on API 6A design calculations for pressure-containing equipment [15]. According to the specification, the allowable equivalent stress (Von Mises stress) during hydrostatic testing should not exceed 90% of the material's minimum specified yield strength. The acceptance criterion, defined as 0.9 times the material's yield strength, is widely adopted in pressure equipment design to maintain an adequate safety margin and prevent premature material failure under extreme conditions [16],[17]. The approach further complies with the fundamental principles of ASME Boiler and Pressure Vessel Code, Section VIII Division 2, which emphasizes stress-based acceptance standards for pressure-retaining components. By implementing these criteria, design validation not only ensures regulatory compliance but also enhances operational reliability and reduces the risk of failure during service [18],[19],[20]. The spool geometry and mesh result of the casing head as shown in Figure 4. The mesh detailed can be seen in Table 6, and 7. While a formal mesh convergence study was not performed, mesh quality was ensured through skewness analysis. The average skewness value of 0.26363 falls within the "good" range according to meshing standards. This, along with the high mesh smoothing setting and uniform element quality, suggests that the simulation results are stable and reliable.

Figure 4: Mesh generates of the casing head

Table 6: Details of mesh

| Parameter | Value |
|---|---|
| Check Mesh Quality | Yes |
| Error Limits | Standard Mechanical |
| Target Quality | Default (0.050000) |
| Smoothing | High |
| Mesh Metric | Skewness |
| Min | 5.70E-07 |
| Max | 0.99999 |
| Average | 0.26363 |
| Standard Deviation | 0.15509 |

Table7: Skewness values

| Value of skewness | Cell quality |
|---|---|
| 1 | Degenerate |
| 0.9 -< 1 | Bad (Sliver) |
| 0.75 - 0.9 | Poor |
| 0.5 - 0.75 | Fair |
| 0.25 - 0.5 | Good |
| > 0 - ≤ 0.25 | Excellent |
| 0 | Equilateral |

The mesh quality was evaluated based on the skewness metric to ensure numerical convergence and solver stability throughout the FEA of the casing head. A high smoothing setting was employed during meshing, achieving a minimum skewness of $5.7019 \times 10^{-7}$, a maximum skewness of 0.99999, an average skewness of 0.26363, and a standard deviation of 0.15509. According to standard meshing guidelines, skewness values between 0.25 and 0.5 are classified as good, while values below 0.25 indicate excellent element quality. With an average skewness of 0.26363, the mesh is predominantly within the good quality range, ensuring that the generated elements are sufficiently regular to produce accurate stress and deformation predictions.

The relatively low standard deviation further indicates that the mesh maintains uniform element quality across the geometry, minimizing potential localized inaccuracies and enhancing the overall fidelity of the simulation. Maintaining good skewness values is particularly critical in hydrostatic pressure simulations, where capturing stress gradients accurately is essential for validating the structural integrity of the design. Thus, the meshing strategy employed in this study provides confidence that the simulation results are both stable and representative of the physical behavior of the casing head under operational loading conditions. The load setup of casing head is as shown in Figure 7. The simulation results for hydrostatic at a pressure of 7500 psi as shown in Figure 8.

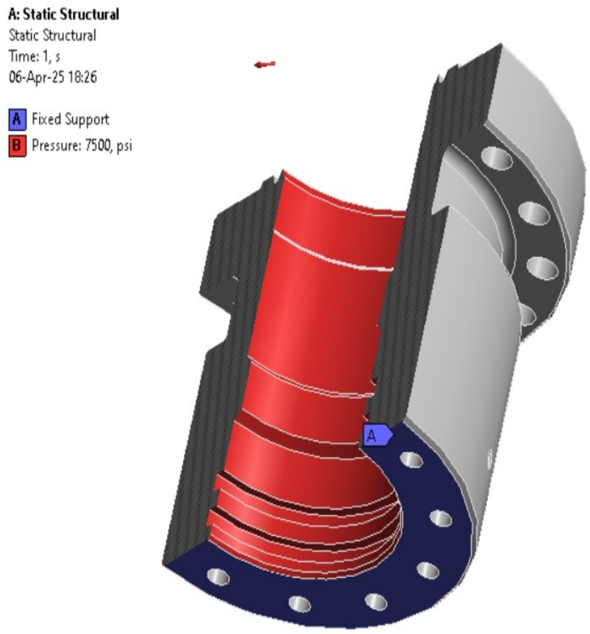


Figure 7: Load setup of spool

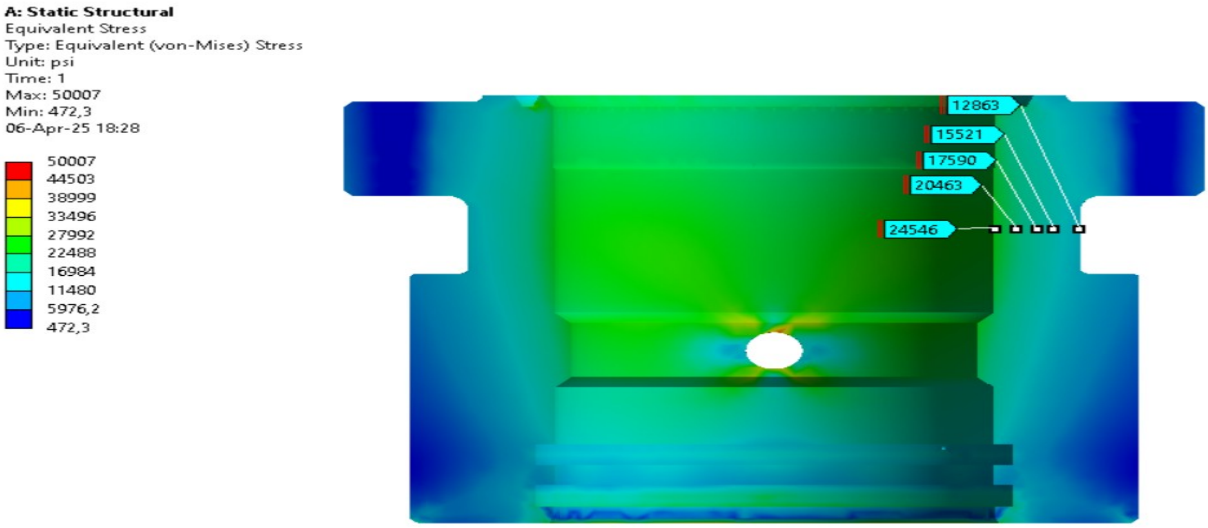


Figure 8: Simulation for 7500 psi using AISI 4130

In the finite element analysis, the simulation was initially conducted using the material with the lowest yield strength, AISI 4130 (Figure 8), which has a hydrostatic test acceptance limit of 67,500 psi (0.9 × yield strength). The result of the simulation shows that the maximum von Mises stress remains significantly below this threshold. This indicates that the design is structurally safe under the given loading condition. Consequently, the analysis can be reasonably extended to materials with higher yield strength, such as Stainless Steel 410, without repeating the simulation, since their acceptance criteria are more tolerant (72,000 psi). This approach follows a conservative design principle, where validating the weakest case inherently validates the stronger ones.

### 3.2 Deformation

A simulation analysis was carried out to evaluate the deformation stress behavior of a component subjected to a simulated pressure test of 7,500 psi. This simulation aimed to assess how the component would respond under high-pressure loading conditions, which are representative of the operational demands it would encounter during service. Simulating such extreme conditions is a critical step in ensuring that the component can maintain its structural integrity, dimensional stability, and operational performance without experiencing unacceptable deformation. The deformation stress analysis focuses particularly on how much the material deflects or changes shape when exposed to this pressure, as excessive deformation could lead to functional failure, loss of sealing capability, or safety hazards in real-world applications. To ensure reliable and consistent performance, an acceptance criterion was established, setting the allowable maximum deformation at 1% of the thinnest wall thickness at the most critical region of the component. In this particular case, the critical area was identified at the necking zone, located 18.88 inches along the component's structure. This region was selected based on its geometric characteristics and stress concentration potential under applied pressure loads. The deformation limit was defined in accordance with industry-recognized standards and technical guidelines provided by the American Society for Metals (ASM) [14], a highly regarded authority in the field of materials engineering. These standards are widely adopted to ensure consistent, validated, and safe evaluation of mechanical components subjected to various operational stresses and conditions.

To comply with the specified criteria, the maximum permissible deformation was calculated as 1% of the 18.88-inch wall thickness, resulting in an allowable deformation value of 0.018 inch. This calculation ensures that the structural integrity of the component is maintained under the specified pressure conditions. During the simulation, the deformation response of the component was closely monitored, particularly in the identified necking area, to verify whether the material performance met the required standards. The simulation results indicated that the maximum deformation experienced by the component under a simulated pressure load of 7500 psi was 0.00006112 inch, which is significantly lower than the allowable deformation limit of 0.018 inch. This outcome highlights a substantial safety margin, demonstrating the component's capability to withstand the applied pressure without significant structural deformation or risk of failure.

The considerable difference between the actual deformation and the permissible limit underscores the robustness of the design and the effectiveness of the material in maintaining structural integrity under high-pressure conditions. Furthermore, the deformation distribution across the component was visually represented in Figure 9, providing a clear illustration of how the material responds to the applied pressure. This visual representation is crucial for understanding the areas of the component that experience the most stress and deformation, allowing for targeted improvements and validations in the design process. The detailed analysis and visual data collectively confirm that the component is well within the safety and performance parameters, ensuring reliability and durability in practical applications. In summary, the finite element analysis has not only verified the structural integrity of the casing head design under critical pressure conditions but also provided a comprehensive understanding of the deformation behavior of the material. The substantial safety margin observed in the-


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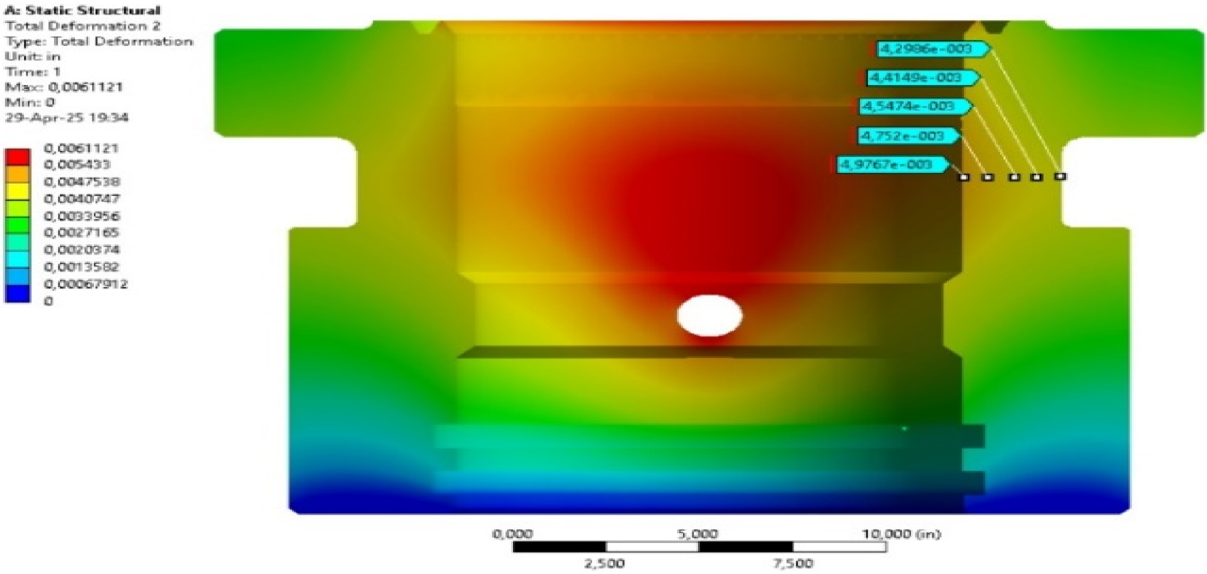


Figure 9: Deformation distribution

simulation results affirms the suitability of the design for manufacturing, offering flexibility in material selection without compromising safety, compliance, or mechanical reliability.

Based on these results, it was concluded that the component successfully met the deformation stress acceptance criteria under the applied simulation conditions. The assessment was officially classified as "Accepted" since the observed maximum deformation was far below the permissible limit, confirming that the component's design and material properties are suitable for the intended operational environment. This conclusion reinforces confidence in the structural integrity, safety, and operational reliability of the component when subjected to high-pressure conditions, ensuring compliance with the applicable industry standards and maintaining service performance expectations.The validation was conducted by comparing simulation results with established acceptance criteria from API 6A standards for allowable stress and ASM guidelines for maximum deformation. By evaluating the most conservative case using AISI 4130 with lower yield strength and ensuring all stress and deformation outcomes remained well below allowable limits, the simulation provides a validated basis for structural integrity.

## 4.0 DISCUSSION

Based on the results obtained from the simulation analysis described above, it can be concluded that the points experiencing the highest loading and deformation conditions have been clearly identified and are detailed in Table 8. These specific points correspond to the areas of the component subjected to the greatest stress concentrations and the most significant deformation responses under the applied pressure load of 7,500 psi. Identifying these critical regions is essential in any structural analysis, as it allows engineers to evaluate the material behavior under operational conditions and ensure that no part of the component exceeds the allowable stress or deformation limits. By accurately locating the points of maximum loading, it becomes possible to predict potential failure zones, assess the safety margins, and verify the effectiveness of the component's design. The data presented in Table 8 serve as a valuable reference for understanding the component's performance under simulated test conditions and provide essential input for any further design improvements, validation activities, or operational risk assessments that may be required.

Table 8: Result of simulation

| Casing Spool 13-3/8 5K × 13-3/8 5K (AISI 4130) | | | | | |
|---|---|---|---|---|---|
| No | Component | Acceptance Criteria | Casing Load | Remarks | Conclusion |
| 1 | Strength | Maximum stress is 67,500 psi (0.9 x material yield strength hydrostatic test) (API 6A x design calculation for pressure containing equipment) | 18,196 psi | Stress at casing lower than strength on material AISI 4130 | Acceptable |
| 2 | Deformation | Maximum allowable deformation is 1% (0.018 inch) of the thinnest wall thickness at the necking area, located 18.88 inches along the component | 0.00006112 inch | Deformation stress lower than maximum allowable deformation | Acceptable |


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The simulation results indicate that AISI 4130 is highly suitable for the casing head design under a hydrostatic pressure of 7,500 psi. The calculated equivalent stress of 18,196 psi, along with a deformation of 0.00006112 inches, remains well within the allowable limits specified by API 6A and ASM standards. These findings confirm the structural integrity, reliability, and safety of the proposed design. The analysis demonstrates that the material can withstand the applied pressure without significant deformation or risk of failure, ensuring the component's durability and performance in practical applications.

Additionally, the substantial safety margin observed in the simulation results further validates the robustness of the design, providing confidence in its ability to maintain structural integrity under critical pressure conditions. This comprehensive evaluation underscores the effectiveness of AISI 4130 in meeting the stringent requirements for pressure-containing equipment, making it a reliable choice for manufacturing the casing head design. Although physical testing is not conducted within the scope of this study, the simulation was designed using a conservative approach by modeling the material with the lower yield strength (AISI 4130).This method provides a reliable reference, as materials with higher yield strength, such as SS 410, would inherently pass the same design criteria. The simulation results indicate that the design meets the strength and deformation criteria with a large safety margin. The maximum simulated stress was only 18,196 psi, which is 27% of the allowable limit (67,500 psi), indicating a safety margin of 370%. The maximum deformation was 0.00006112 inch, significantly lower than the allowable 0.018 inch, representing a margin of over 295 times. the results are confidently believed to represent 100% alignment with the intended real-world performance.  Nevertheless, future work is recommended to include experimental validation for further confirmation.

## 5.0 CONCLUSION

Based on the finite element analysis (FEA) results, the 13-3/8" 5K casing head design was evaluated under a hydrostatic pressure of 7500 psi, confirming that AISI 4130 Alloy Steel meets the structural integrity and safety requirements according to the acceptance criteria. The equivalent (Von Mises) stress observed in the simulation was approximately 18,196 psi, with a deformation of 0.00006112 inch well below the allowable stress and deformation limits defined for pressure-containing equipment. The primary objective of the simulation was to verify the reliability of the casing head design, ensuring that structural integrity would be maintained even when tested with a material of relatively lower mechanical strength, such as AISI 4130. Since AISI 4130 successfully met the acceptance parameters under critical pressure conditions, it can be inferred that Stainless Steel 410, which possesses comparable or superior tensile properties, would also ensure adequate structural performance. The casing head design is therefore considered valid and suitable for manufacturing using either AISI 4130 or SS 410 materials. The use of SS 410 is particularly advantageous in scenarios where ASME-grade alloy steels are difficult to procure or involve higher costs. This flexibility in material selection can optimize operational efficiency without compromising safety, compliance, or mechanical reliability. The FEA results have demonstrated that the casing head design meets all technical and safety requirements and is thus approved for progression to the manufacturing stage. The finished product can subsequently undergo actual hydrostatic pressure testing to validate its performance under real-world conditions.

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