

Structural Integrity Assessment of High-Pressure Vessels for Hydrogen Storage Using Finite Element Analysis

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Abstract: Hydrogen is not only present in the structure of most substances but also attracts attention as a clean energy source. The fact that hydrogen only releases water through combustion and possesses high energy potential provides a significant advantage as an alternative energy source. This paper presents a numerical investigation into the stress and deformation behaviour of high-pressure vessels used in hydrogen production systems. In the study conducted with Finite Element Analysis (FEA), deformation analysis is performed with three different materials, stainless steel NL, alumina, and grey cast iron, in the pressure range of 0-75 MPa. A cylindrical tank with a height of 530 mm and a diameter of approximately 70 mm is utilised. No severe deformation is observed up to 35 MPa with the stainless steel NL material at an 8 mm wall thickness. With increasing wall thickness, the amount of deformation decreases by up to 50% for all three materials. It is highlighted that the usage of alumina as a material in hydrogen storage tanks exhibits a low deformation value at high pressures, particularly with a deformation of approximately 0.3 mm at an 8 mm wall thickness. Additionally, it is determined that 8 mm thick stainless steel NL and grey cast iron tanks meet the safety requirement for a pressure of 10 MPa, but for alumina, the safety factor drops to 2 under the same conditions. The tank's volumetric capacity of 0.0257 is found to be at an acceptable level.

Keywords: Hydrogen Storage, High-Pressure Vessel, CFD Simulation, Finite Element Analysis

Introduction

Today, a large portion of global energy consumption is met by fossil fuels. The world is facing a critical environmental crisis due to the widespread use of fossil fuels, which brings about alarming levels of greenhouse gas emissions and environmental pollution (Shi et al., 2023). Fossil fuels are a crucial source of energy to meet immediate needs, but their reserves are depleting day by day due to their use. As fossil fuel reserves continue to decline, the inevitability of switching to alternative energy sources has become increasingly evident. Considering all these factors, the need for sustainable and clean energy

sources with minimal environmental impact is growing (Karabuga et al., 2026). Hydrogen, a clean and versatile energy carrier, has emerged as a convincing solution to address these urgent concerns. The potential of hydrogen as a clean energy source lies in its ability to be produced from a wide range of renewable and sustainable sources, including electricity generated from renewable power sources such as water, biomass, solar and wind (Zhang et al., 2016). Moreover, the use of hydrogen as a fuel does not cause any direct greenhouse gas emissions, making it an environmentally friendly alternative to traditional fossil fuels (Le et al., 2023). Hydrogen stands out as an important alternative energy source due to its abundance,

its role as a clean energy carrier, and its diverse applications. Hydrogen can be produced by a wide variety of methods, including water electrolysis, biomass gasification and thermochemical processes (Jain et al., 2010; Vidas and Castro, 2021). In particular, the electricity required for water electrolysis can be obtained from renewable energy sources. Thus, the environmental benefits of hydrogen as an energy carrier are further increased, and it has attracted more attention as a promising hydrogen production technique (Li et al., 2021). However, the successful widespread adoption of hydrogen as a clean energy source depends on the development of efficient and cost-effective hydrogen storage solutions. Hydrogen storage is a crucial aspect of the hydrogen energy ecosystem as it enables the transportation, distribution and long-term storage of this versatile energy carrier (Preuster et al., 2017). Hydrogen is stored in different ways in practice. Hydrogen can be stored in a variety of forms, including compressed gas, liquid hydrogen and solid-state storage using metal hydrides or other materials. Each storage method has its own advantages and limitations, and ongoing research is focused on improving the storage density, safety and cost-effectiveness of these technologies. Liquid and solid hydrogen storage have been identified as particularly promising with advantages such as high density, safety and convenient transportation. Extensive research and development efforts are ongoing to address the challenges associated with hydrogen storage, including improving storage capacity, reducing energy consumption during storage and retrieval processes, and boosting the overall safety and reliability of hydrogen storage systems.

To further advance the development of hydrogen storage technologies, researchers conduct extensive theoretical and experimental analyses. These studies investigate various aspects of hydrogen storage, including the fundamental properties of hydrogen, its behaviour under different storage conditions, and the performance of various storage materials and systems. Computational and theoretical modelling plays a key role in guiding the development of hydrogen storage technologies. These approaches enable researchers to simulate and predict the behaviour of hydrogen under various storage conditions and to investigate the potential of new materials and storage configurations.

Experimental studies are also instrumental in validating theoretical models and guiding the practical implementation of hydrogen storage solutions. Researchers study the kinetics, thermodynamics, and cycling stability of hydrogen storage materials and their integration into functional storage systems.

The combination of theoretical and experimental analyses will be important in advancing the state of the art in hydrogen storage and will lead to the development of more efficient, safe, and cost-effective storage solutions

that can support the widespread adoption of hydrogen as a clean energy carrier. When research on hydrogen storage is examined, it is seen that storage, which is the critical point of the hydrogen energy ecosystem, currently presents difficulties, and despite this, intensive efforts are being made (Di Profio et al., 2009). The development of storage methods, which are of critical importance to support the widespread use of hydrogen, is of great importance. Considering geological and environmental factors as well as efficient compression and storage, it is clear that underground storage solutions present many challenges (Zhang et al., 2015). Great importance is given to the development of materials that enable high-capacity hydrogen storage, including organic porous structures, boron-based compounds and metal-organic compounds. At this point, despite the developing possibilities, improvements in hydrogen storage, release kinetics, and recycling are not yet at the desired level (Lai et al., 2015). The history of hydrogen storage dates back to ancient times. Researchers discuss the advantages and limitations of various storage methods, including compressed gas, cryogenic liquid metal hybrids, and suggest promising directions for future research (Magliano et al., 2024). Overall, current research highlights the critical importance of hydrogen storage in the broader context of the transition to a sustainable energy future and ongoing research efforts to develop more efficient, safe and cost-effective storage solutions.

Hydrogen can be used as an energy carrier and only produces water vapour during combustion processes. This makes hydrogen an environmentally friendly energy option. The electricity required to produce hydrogen is provided by renewable energy sources such as solar, wind and hydroelectricity, which promises to increase energy independence. In addition to being environmentally friendly, hydrogen has a high energy content per mass, i.e. a high energy density (Züttel, 2004). Hydrogen can be used instead of gasoline and diesel in fuel cell vehicles (Durbin and Malardier-Jugroot, 2013). It is also widely used in the chemical, metallurgical and electronics industries. It can be used for energy storage and then returned when needed (Zhang et al., 2015). Hydrogen can also be utilised for heating buildings and generating electricity. All these are more than enough for hydrogen to become widespread. Nevertheless, one of the biggest obstacles to the use and widespread use of hydrogen is the difficulties in storage technologies (Lai et al., 2015). The gravimetric energy density of hydrogen is quite high. In fact, the gravimetric energy density of hydrogen, which is 33.3 kWh/kg, is much higher than most conventional fuels and batteries (Züttel, 2004). Whilst this situation creates an advantage, the low volumetric energy density of hydrogen affects the efficiency and cost of storage systems (Ghorbani et al., 2023). Hydrogen can be stored physically and chemically effectively and safely (Luboń

et al., 2024). Physically, hydrogen can be stored as compressed hydrogen gas in high-pressure tanks (Schüth, 2009), as liquid hydrogen by liquefaction by cooling down to -253°C (Rufford et al., 2006), and by surface absorption of hydrogen in metal-organic frameworks in porous materials (Shet et al., 2021). Chemical storage is seen as hydrogen metal-hydrides and chemical hydrogen carriers. Some of the metals and alloys react with hydrogen to form metal hydrides. These compounds chemically bind hydrogen and release it when needed. Magnesium-based hydrides stand out as potential hydrogen storage candidates (Zhang et al., 2015). Liquid organic carriers and chemical compounds, such as ammonia borane, can store hydrogen through chemical bonds. This method, while providing high storage capacity, requires additional energy or chemical reactions to release hydrogen (Jeong et al., 2021). It is also observed that researchers perform fatigue analysis on storage materials using the finite element method and present detailed deformation analysis on the material (Wu and Yang, 2021; Baragetti et al., 2020).

Although there are different techniques for hydrogen storage, it is crucial to store it in high-pressure containers ready for use in order to provide energy conversion by using it immediately when desired. For this purpose, tanks with various structures made of high-strength materials can be utilised. As a different alternative, it is also possible to store hydrogen ready for use by liquefying it. In this case, the costs and processes required for liquefying hydrogen can complicate the process. Therefore, hydrogen storage in pressure containers is more advantageous in terms of direct use and short processes. Considering that hydrogen has been used as fuel in vehicles in recent years, the importance of hydrogen storage in high-pressure containers is better understood. The most significant progress in this regard is the development of high-strength carbon fibre materials and the reduction of the current weight of tanks. Hydrogen can be stored at very high pressures under suitable conditions. In fact, it can be stored in specially produced cylinders and containers, as well as in underground cavities in gaseous form by pressurising it up to 700 bar (Zhang et al., 2016). Yamashita et al. (2015) claim that using two 70 MPa tanks instead of four 35 MPa tanks in a car reduces the weight by 15% and increases the range up to 500 km. Hydrogen storage and transportation using high-pressure containers is a situation that requires extremely high safety standards. Therefore, the strength and durability of storage tanks require detailed analysis.

It is neither possible nor economical to test the strength of storage tanks by experimental means under all conditions. It is complicated to conduct experimental studies, especially for each model with its own unique design and size. Therefore, it is quite practical to test the

strength of storage tanks economically with FEA. It is clear from the studies in the literature that the results of the analyses made with FEA are quite acceptable with the experimental results (Lin et al., 2021). Wang et al. (2015) test the deformation and burst strength of a tank made of aluminium-carbon fibre/epoxy composite material with ABAQUS engineering commercial software using FEA. They report that the onset of damage is observed in the head joint section and, in general, in the cylindrical tank under 60-80 MPa pressure, and the container collapses by bursting at 94.3 MPa. They claim that the results obtained with FEA are quite consistent with the experimental data. Similarly, different researchers claim that they have achieved successful results in damage analyses conducted on cylindrical tanks using the FEA method (Liu et al., 2014).

In this study, FEA method is used to test the strength of hydrogen storage tanks. A 3D FEA model of cylindrical tanks commonly used for hydrogen storage is created, and its strength is tested for three different materials. Especially when the cost of hydrogen storage is considered, the type of tank material and the optimisation of maximum strength are very important. Therefore, by analysing three commonly used tank materials under different pressures, the maximum amount of hydrogen that can be stored and the tank weight are evaluated together to perform ideal material selection and pressure range analysis. It is commonly seen in the literature that tank weight and storage capacity are not evaluated together, although researchers evaluate them with the FEA method in fixed geometries with a single material. Details regarding the process steps carried out in the study are given in Figure 1.

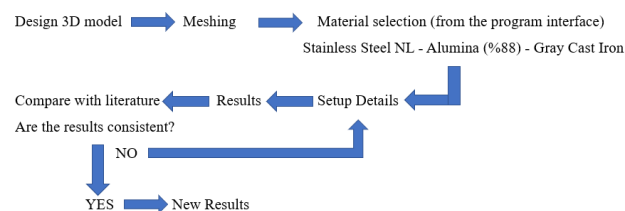


Fig. 1: Steps in the analysis procedure for the FEA

Methodology

Hydrogen possesses great potential with its high energy density and environmentally friendly fuel properties. In this study, FEA is performed with a tank model designed to ensure the use of hydrogen as an energy source and to transport it safely with high storage capacity. A 3D model is used in the analysis performed using the ANSYS engineering commercial software student version. The created 3D tank model, three different wall thickness details and mesh structure are given in Figure 2. Whilst analysing the storage tank, the

inner surfaces in contact with the hydrogen to be stored are exposed to different values in the 0-75 MPa pressure range, provided that the circular section base of the tank is kept fixed. In the evaluation performed in a wide pressure scale, tank analyses are also repeated for 4 mm, 6mm, and 8 mm wall thicknesses and tank analyses are performed. The tank used in the analysis has a length of 530 mm and a diameter of 70 mm.

The three different materials used in the analysis are stainless steel, alumina (88%), and grey cast iron. When analysing with stainless steel material, non-linear material is preferred since the material will not show linear properties under different pressures. The physical properties of the three different materials are given in Table 1. In material selection, materials widely used in the literature and suitable for hydrogen storage are preferred. Before moving on to the analysis for different wall thicknesses and different materials, the independence of the analysis from the number of cells is tested. For this purpose, a mesh-independent solution is made on the total deformation and equivalent stress values for the 4, 4.5, and 5 mm element sizes of the tank with 8 mm wall thickness and 30 MPa pressure with stainless steel NL material, respectively. Details of the mesh-independent solution are given in Table 2. It is demonstrated that there is no significant difference in the results for the number of elements for different cell sizes, and the minimum cell

size of 4 mm is taken as the basis. Materials are selected from the Engineering Data interface in the student version of ANSYS engineering commercial software using the "Engineering Data Source" option. Because the tank contains high-pressure hydrogen gas as a boundary condition, equal pressure is applied to the entire interior surface of the tank. The "support" option is then used for the tank top and bottom. For solver settings, the total deformation and equivalent stress as a function of the pressure applied to the tank are added to the results section.

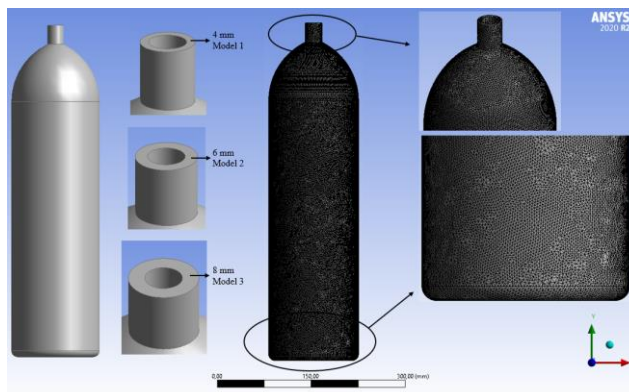


Fig. 2: 3D FEA model, three different wall thicknesses, and mesh images

Table 1: Materials used in the analyses and their physical properties

Properties / Materials	Stainless Steel NL	Alumina (%88)	Grey Cast Iron
Density (kg/m ³)	7750	3475	7200
Young's Module (MPa)	1.93x10 ⁵	2.459x10 ⁵	1.1x10 ⁵
Poisson's Ratio	0.31	0.2392	0.28
Yield Strength (MPa)	210	200	250
Tangent Modulus (MPa)	1800	-	-

Table 2: Mesh independent solution in detail

Element size (mm)	Elements	Nodes	Total Deformation (mm)	% change	Equivalent Stress (MPa)	% change
5	80043	141626	0.32689	-	258.55	-
4.5	96346	172661	0.32729	0.122	241.64	-6.54
4	116047	209543	0.32696	-0.1	236.28	-2.21

After obtaining the mesh-independent solution, the usability of the FEA model continues with the verification phase. In particular, it is imperative to compare simulation studies with experimental and similar studies in the literature. Designs similar to the tank model used in the study are compared with the data obtained from experimental and FEA studies conducted by researchers. There are researchers who present that hydrogen can be stored at pressures up to 70 MPa with a carbon fibre-added tank in their FEA study (Hua et al., 2017). In another study, researchers report that the experimental pressures of the hydrogen storage tanks. they produced are

65.7 MPa in steel liners, 27.9 MPa in aluminium liners, and approximately 90 MPa in hybrid designs covered with glass fibre (Kangal, 2019). Even though the same materials are not directly used in the study, it is highlighted that the outcomes obtained for the same pressure values are compatible with the literature. In the study conducted, the average maximum deformation with a 60-65 MPa pressure using stainless steel NL material with a 4 mm wall thickness exceeds 15 mm, which is consistent with the explosion pressure reported in the literature (Kangal, 2019). Similarly, some researchers perform FEA using ANSYS engineering commercial

software with materials having a 4 mm wall thickness. They interpret the amount of deformation under high pressure by coating the storage tank, made of nickel and titanium materials, with alumina and zirconium. They claim that there is a minimum of 0.00625 mm and a maximum of 19.54 mm of total deformation under a pressure of 60 MPa (Senthil Kumar et al., 2020). Similarly, in the study conducted, the total deformation with stainless steel NL (non-linear) material under 4 mm wall thickness and 60 MPa pressure is found to be 22.3 mm, which is quite consistent with the literature. A total deformation comparison is made for the study conducted under 4 mm wall thickness and 60 MPa pressure, and a similar study conducted with the FEA method in the literature. The comparison details are given in Figure 3. The data presents the values where the total deformation amount is maximum and minimum. The graph sheds light on the consistency of the results in the study, as supported by the literature data. The analysis is performed using a total of 135 different solutions, with results obtained at 15 different pressure values for three different materials. The mesh density is presented by considering a mesh-independent solution, and pressure is applied to the inner surface of the tank to represent the solid-gas interface as a contact point. The reference state is not changed and is kept constant at 10^{-6} as the convergence criterion.

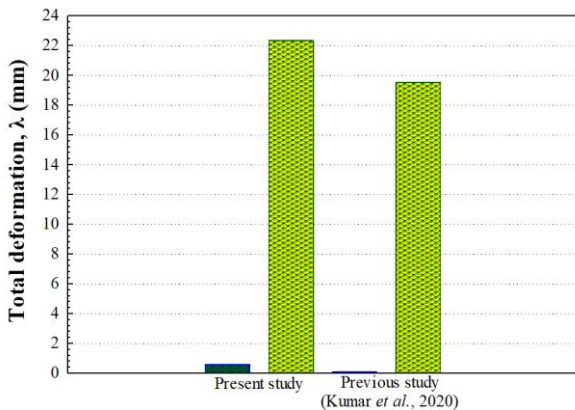


Fig. 3: Comparison of maximum total deformation for different materials under 4 mm wall thickness and 60 MPa pressure for the conducted study and similar studies in the literature

Results and Discussion

Hydrogen, despite its great promise for clean energy, does not receive the attention it deserves due to storage costs and difficulties in transportation. Although there are different methods for storing hydrogen, storing it as a gas ready for use under high pressure is the most convenient way. In this study, analyses are performed under different pressures for different materials with the 3D FEA model created to evaluate the storage of hydrogen as a gas under

high pressure. For the stainless steel NL material, total deformation is examined under different pressures with tanks with 4, 6, and 8 mm wall thicknesses, respectively. Then, the solutions are repeated for different tank materials. The total deformation contours occurring in the tank for the stainless steel NL tank material with 4 mm, 6mm, and 8 mm wall thicknesses under 30 MPa pressure are given in Figure 4, respectively.

It is a natural expectation that the amount of deformation decreases under the same pressure for the material with increasing wall thickness. Since the wall thickness is doubled to 8 mm, the decrease in the total deformation amount under 30 MPa pressure is remarkable. There is a non-linearity relationship. Although increasing the wall thickness is quite suitable for tank strength, undesirable situations may arise due to parameters such as weight and cost. The total deformation graph for three different wall thicknesses at different pressure values for stainless steel NL material is given in Figure 5. It is a natural expectation that the amount of deformation increases with increasing pressure for all three wall thicknesses. However, it is clear that the pressure at which the amount of deformation can be clearly observed increases with rising wall thickness. It is observed that the amount of deformation remains almost constant up to a value of 15 MPa for a wall thickness of 4 mm, and then increases significantly beyond this point.

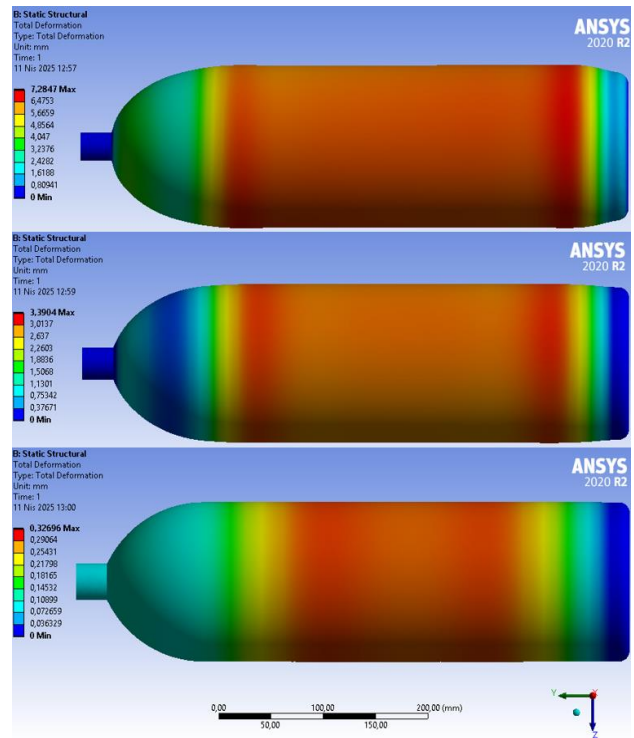


Fig. 4: Total deformation contours for wall thicknesses of 4 mm, 6 mm, and 8 mm, respectively, under 30 MPa pressure with stainless steel NL tank material

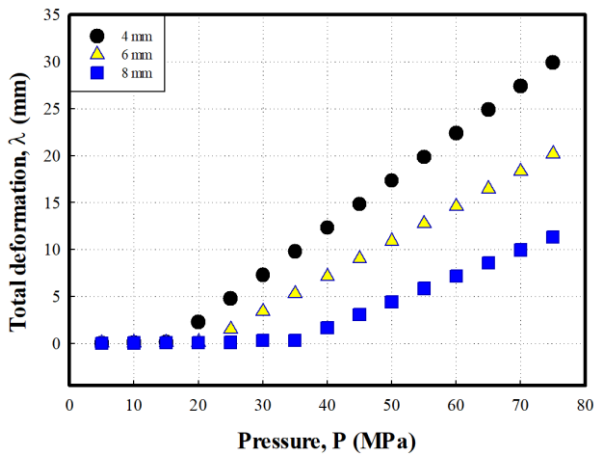


Fig. 5: Total deformation graph of the tank produced using stainless steel NL material for 4 mm, 6 mm, and 8 mm wall thickness at different pressures

It is shown that the pressure value at which the deformation can be clearly observed is 20 MPa for a wall thickness of 6 mm and 35 MPa for a wall thickness of 8 mm. In this case, it can be concluded that choosing the wall thickness according to the usage pressure for the hydrogen storage tank made of stainless steel NL material is the correct approach.

The material of the tank is as important as the tank wall thickness. After the first results are obtained for stainless steel NL, solutions are repeated for alumina and grey cast iron at different pressures for 4 mm, 6mm, and 8 mm wall thicknesses. Due to the different physical properties of the three materials, they show different deformations in response to increasing pressure values. Total deformation graphs of the two materials alumina and grey cast iron with 4 mm, 6 mm, and 8 mm wall thicknesses are given in Figure 6. As expected, the amount of deformation increases with increasing pressure for three different wall thicknesses. Especially compared to stainless steel NL material, alumina and grey cast iron appear to be more usable as tank materials for hydrogen storage. When alumina material is used with a wall thickness of 4 mm in the 75 MPa maximum pressure analysis, the top deformation is 0.66 mm, which corresponds to 16.5% of the wall thickness. When alumina is used as a tank material, the total deformation is 0.307 mm under 75 MPa pressure with 8 mm wall thickness, which is less than 5% of the wall thickness. Tank weight is as important as durability in hydrogen storage. The tank sample used in the analysis is approximately 22 kg in weight and composed of alumina material. In the case of grey cast iron, the weight is approximately 45.5 kg. For grey cast iron material, the total deformation contours for 4 mm and 8 mm wall thickness under 30 MPa pressure are given in Figure 7.

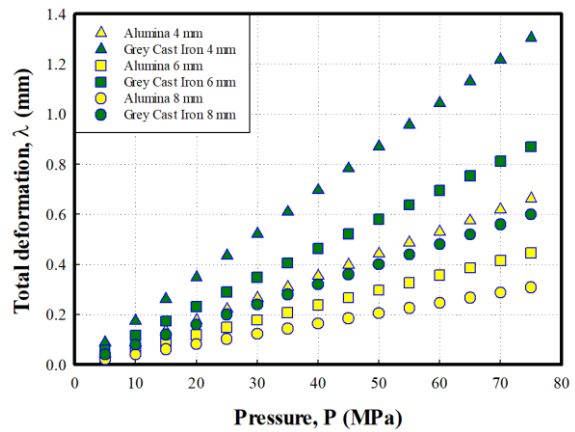


Fig. 6: Compressive total deformation graph for alumina and grey cast iron with 4 mm, 6 mm, and 8 mm wall thickness

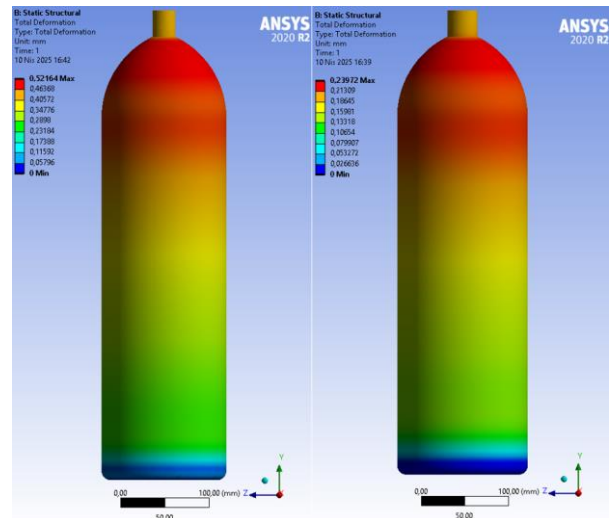


Fig. 7: Total deformation contours of tanks with wall thicknesses of 4 mm and 8 mm under 30 MPa pressure for grey cast iron material

Whilst hydrogen is a clean energy source, as evidenced by the study's findings, its storage presents significant challenges. The high pressure caused by storing large amounts of hydrogen can pose a significant safety vulnerability in storage tanks. The study clearly demonstrates that hydrogen will be stored at higher pressures as wall thickness increases in storage tanks with 4, 6, and 8 mm wall thicknesses. While the total deformation at 30 MPa for an 8 mm wall-thick hydrogen storage tank appears low, the Equivalent Stress (Von Mises) value of 236.28 MPa is greater than the yield strength for stainless steel NL (210 MPa). This can lead to deterioration in the tank's physical structure, posing security threats, and storage above 25 MPa poses a risk.

Safety Factor, Storage Capacity and Future Studies

Hydrogen, while possessing great potential for clean energy, is a gas that requires very high safety measures due to the risks of leakage and explosion. This investigation, which analyses tank strength at varying pressures for different wall thicknesses and materials, clearly shows that wall thickness is critical for safe storage. On the other hand, when evaluating the safety range mandated by international standards, the ratio of yield strength to available stress, which is the safety factor, is taken as 2.25 (Sapre et al., 2020). A comparative graph for an 8 mm tank thickness at different pressures is given in Figure 8 when comparing the safety factors of 3 different materials. As seen in the graph, when stainless steel NL and grey cast iron are used as materials for an 8 mm tank thickness, the safety factor is almost achieved at pressures of 10 MPa and below, whereas the same is not true for alumina. The literature shows that similar cylindrical tanks produced with metallic materials have been tested for pressure resistance of 17.5-20 MPa (Barral and Barthélémy, 2006). The study determined that the safety factor for the materials used is 1-1.5 at the same pressure values. While this is acceptable, expanding the studies to include tanks of different thicknesses and conducting analyses for different tank designs will yield more detailed results.

In storage systems, storage capacity is as important as safety. While a system volumetric capacity ($\text{kg H}_2/\text{litre}_{\text{system}}$) of 0.03 is considered acceptable as of 2020, this level is expected to increase in the coming years (Magliano et al., 2024). The results regarding the volumetric capacity of the system for this study are given in Table 3. Currently, storage capacity can be increased by the tank length increment. For a detailed analysis of the stresses that will occur in this case, it is necessary to perform stress analyses at different tank lengths and compare them. In future studies, stress analyses of different length designs for a standard tank diameter will be performed and compared.

For all three materials, the safety factor remains at acceptable levels under 10 MPa pressure, but it is observed that the safety factor decreases at higher pressures. On the other hand, all three materials meet the standard safety factor requirement for 5 MPa pressure. This is an acceptable pressure level, especially for thin-walled storage tanks to be produced at this scale. The system's ability to safely store energy at higher pressures within safe limits can be increased, but this will rise the

wall thickness. Therefore, the design and pressure resistance in this study are within allowable limits. For stainless steel, equivalent stress levels above the yield strength are reached at 30 MPa. This situation necessitates the use of specially manufactured composite-coated tanks instead of standard tanks at these pressure values, especially for hydrogen storage tanks to be made of stainless steel. On the other hand, an alternative is to increase the wall thickness, which will increase the tank weight and reduce the unit storage capacity, which is undesirable. Type 3 and 4 hydrogen storage tanks can be safely used under a pressure of 70 MPa (Piraino et al., 2025). However, these tanks are manufactured using both internal special coatings and external composite materials. This presents a significant disadvantage in terms of cost. The development of more compact and mobile systems, as seen in the ongoing research, is crucial, especially for small-scale storage systems. The study results show that the system capacity of 25.7 grH₂/L under 10 MPa pressure is in the range of 40-60 according to international standards, but these standards are particularly valid for high-strength composite containers (O'Malley et al., 2015). In this case, the findings of the study are quite suitable for use, especially for low-cost and small-scale portable systems. Similarly, since a safety factor of 2.25 is accepted as the standard, it is clear that all three materials can be safely used for small-scale and portable systems at 5 MPa pressure in the conducted study (Law et al., 2013).

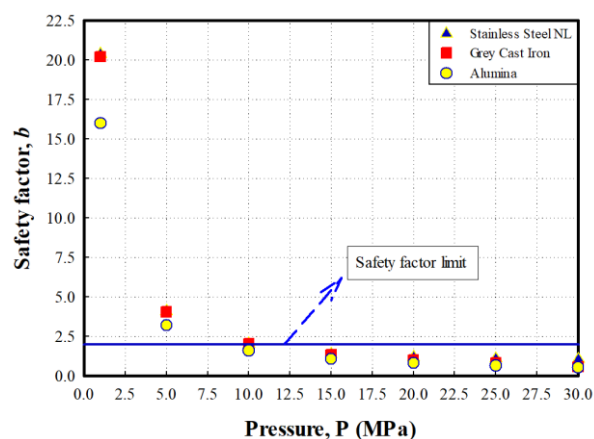


Fig. 8: Graph showing the safety factor at varying pressures for 3 different materials and an 8 mm tank thickness

Table 3: Details regarding tank storage capacity and a comparison with current targets

System volume (Litre)	Density at 10 MPa ($\text{Kg H}_2/\text{m}^3$) (Franco and Giovannini, 2024)	System Volumetric Capacity (Aim)	System Volumetric Capacity (Present study)
1.895	7.8	0.03 (Magliano et al., 2024)	0.0257

Conclusion

Hydrogen has emerged as a promising alternative to fossil fuels by offering a clean and sustainable energy source that can help reduce the environmental impact of greenhouse gas emissions. However, the widespread adoption of hydrogen as an energy carrier is largely dependent on the development of efficient and cost-effective storage solutions. Extensive research and development efforts are being conducted to address the challenges associated with hydrogen storage, including the development of advanced materials and storage systems that can meet stringent requirements such as density, safety, and energy efficiency. Although significant progress has been made, much work remains to be done to fully realise the potential of hydrogen as a clean energy solution. Continued research and development, combined with strategic investments in infrastructure and policy support, will be crucial to ensuring the widespread adoption of hydrogen storage technologies and leading to a more sustainable energy future (Miocic et al., 2023; Yuan, 2023; Tarhan and Çil, 2021). In this study, the deformation of tanks used for hydrogen storage under different pressures is analysed using the 3D FEA method. The analyses are repeated for different pressure values and three different materials: Stainless steel NL, alumina, and grey cast iron. The critical findings obtained from the study can be listed as follows:

- FEA is very useful for analysing hydrogen storage tanks
- The widely used stainless steel NL material can be used for hydrogen storage tanks. Tanks with a wall thickness of 4 mm give very good results up to 15 MPa pressure values, while this value increases to 20 MPa with a wall thickness of 6 mm and up to 35 MPa with a wall thickness of 8 mm
- Deformation of hydrogen storage tanks decreases significantly with increasing wall thickness
- The use of alumina and grey cast iron as tank materials offers less deformation at high pressures
- The amount of deformation of the hydrogen tank with 8 mm wall thickness produced using stainless steel NL material at 50 MPa is approximately 27 times greater than the deformation of the tank produced with alumina material under the same conditions
- The safety factor for a pressure of 10 MPa is 2.25 for stainless steel NL and grey cast iron, while it drops to 2 for alumina. A decrease in the safety factor for higher pressures is a natural expectation
- The system's volumetric storage capacity is 0.0257, which is in line with recent hydrogen storage targets

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Authors Contributions

Pinar Mert Cuce and Erdem Cuce: Conceptualization, methodology, investigation, write review and edited, supervision, project administration.

Harun Sen: Write original draft, formal analysis, visualization, data curation.

Emre Alvrur and Tamer Guclu: Write original draft, visualization.

Ethics

This study is an editorial study and does not involve human participants, animal experiments, or the use of identifiable personal data. Therefore, ethical approval and informed consent were not required.

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