iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL
FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: V Month of publication: May 2025

DOI: https://doi.org/10.22214/ijraset.2025.70443

The Integration of Design Software (PVElite, AutoCAD, Caesar II) in Pressure Vessel and Piping Engineering

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Abstract: Effective design of pressure vessels and piping relies on the integration of CAD and CAE software to guarantee structural integrity and compliance with industry standards. This paper analyzes the integration of PVElite, AutoCAD, and Caesar II, focusing on its impact on design accuracy and its support for advanced analysis. The integrated workflow is explored, encompassing initial 3D modeling using AutoCAD, pressure vessel design and analysis using PVElite (following ASME Section 8), and pipe stress analysis using Caesar II (applying codes such as B31.3). The research investigates how this integration reduces errors in stress calculations, optimizes the placement of supports, and improves the accuracy of material quantity estimations. The paper also discusses the challenges of maintaining data integrity across platforms and emphasizes the importance of a unified modeling environment, providing examples from real-world applications.
Keywords: Indian Oil, PVElite, AutoCAD, Caesar, BITS Pilani, CGWB, Ministry of Jal Shakti.

I. INTRODUCTION

Numerous industrial sectors rely heavily on pressure vessel and piping systems, which are crucial for the storage, transportation, and processing of fluids and gases. Their role is particularly significant in the oil and gas industry, where they are indispensable across upstream, midstream, and downstream operations. Given the potential for catastrophic outcomes from failures, including environmental damage, economic losses, and safety hazards, the integrity and reliability of these systems are paramount. The design and engineering of pressure vessel and piping systems involve a complex, multifaceted process, incorporating principles of mechanical engineering, materials science, and structural analysis. This process generally encompasses several key phases: conceptual design, detailed design and drafting, stress analysis, material selection, fabrication, and inspection.

Over the years, the tools and methodologies employed in the design of pressure vessel and piping systems have seen substantial changes. Early stages involved manual design and drafting techniques. The arrival of computer-aided design (CAD) software, however, transformed the industry, allowing engineers to produce accurate 2D and 3D models with improved efficiency. The increasing complexity of designs subsequently necessitated more sophisticated analysis capabilities. Computer-aided engineering (CAE) software, exemplified by finite element analysis (FEA) programs, emerged as a solution, enabling the simulation and analysis of pressure vessel and piping system performance under various operational scenarios. Despite these technological leaps, a consistent difficulty has been the effective integration of the different software tools utilized across the design workflow.

Historically, design and drafting were typically carried out in CAD software, while stress analysis was performed using separate CAE programs. This separation required manual data transfer between applications, a process that was time-consuming, labor-intensive, and susceptible to errors. This lack of seamless data exchange created obstacles to collaboration among design teams and hindered the optimization of the design workflow.

This paper addresses the important issue of software integration within pressure vessel and piping engineering by examining the interoperability of three key software applications: AutoCAD, PVElite, and Caesar II. AutoCAD is utilized as the primary CAD software for generating detailed 2D and 3D models of piping layouts, pressure vessel components, and support structures. PVElite is specialized software employed for the design and analysis of pressure vessels and heat exchangers, ensuring adherence to industry codes and standards such as ASME Section VIII Division 1. Caesar II is the industry-standard software for pipe stress analysis, used to evaluate piping systems under various loading conditions, including pressure and temperature.

This research investigates how the integrated use of these software tools enhances the design process by enabling seamless data exchange, automating repetitive tasks, and improving design accuracy.

The benefits of this integration, including reduced design iterations, improved collaboration, and enhanced design optimization, will be analyzed. Furthermore, the paper will explore the challenges related to software integration and discuss potential solutions. Practical examples and case studies, drawing from experience in the oil and gas industry and the author's work at Mahathi Infra Services Pvt Ltd, where firsthand experience with these software tools was gained, will be used to illustrate the key concepts and findings.

II. METHODOLOGY

A. *Piping Stress Analysis using Caesar II*

1) Modeling: A 3D model of the piping system was created in Caesar II, incorporating pipe geometry, material properties, and support locations. The B31.3 code was used for design compliance.
2) Analysis: Static analysis was performed to calculate displacements and stresses. For example, displacement at Node 210 was 1.0680 mm.
3) Optimization: Hangers were strategically placed to reduce stress intensity factors (SIF). The SIF at a critical node was reduced from 1.0680 to 0.860**.**

B. *Sprinkler System Design using AutoCAD*

1) Drafting: 2D layouts of sprinkler systems were designed in AutoCAD, incorporating equal tees and reducing tees.
2) Design Specifications: Design included "SPRINKLER RISER FOR 1LPM" and "SPRINKLER RISER FOR 3 LPM".
3) Support Structure: An angle support (IS 2850) was designed at a 45-degree angle.

C. *Pressure Vessel Design using PVElite*

1) Modeling: 3D models of the pressure vessels were generated using PVElite, with shell dimensions (e.g., SHELL2: 3200 mm outside diameter, 250 cm length) and material properties (e.g., SA-516 70) defined in accordance with ASME Section VIII Division
2) Analysis: Calculations were performed to establish the required shell thickness and Maximum Allowable Working Pressure (MAWP). For example, the Hydrostatic Test Pressure was calculated as 12.456 kgf/cm^2.
3) Material Selection: Materials were specified as follows: SA-516 70 for the shell and head, and SA-106 B for the nozzles.

III. DISCUSSION

The integration of specialized software tools such as PVElite, AutoCAD, and Caesar II plays a crucial role in the efficient and accurate design and analysis of pressure vessels and piping systems, which are fundamental components across numerous industrial sectors, including the oil and gas industry

Caesar II facilitates the design and comprehensive stress analysis of piping systems, ensuring adherence to international codes like B31.3. Its capability to model and simulate diverse loading scenarios enables the optimization of piping layouts to minimize critical stress intensity factors (SIF), as evidenced by the reduction of SIF achieved through the strategic implementation of hangers [as potentially observed during the work on the Uganda pipeline project]. This process is paramount for enhancing the reliability and operational safety of piping systems, particularly within the demanding environment of the oil and gas sector.

AutoCAD is instrumental in the design and precise drafting of sprinkler systems, allowing for the creation of detailed layouts incorporating essential components such as equal and reducing tees [potentially relevant to the sprinkler ring designs for IOCL]. The accuracy afforded by AutoCAD in representing and placing system components is vital for ensuring effective fire protection capabilities in industrial facilities.

PVElite streamlines the design process for pressure vessels by offering integrated tools for modeling, analysis, and evaluation. This software assists in determining critical design parameters, including shell thickness and Maximum Allowable Working Pressure (MAWP), thereby ensuring that vessels are designed to safely withstand anticipated operating pressures and temperatures. The application of PVElite, in accordance with industry standards like ASME Section VIII Division 1, is essential for establishing and maintaining the structural integrity of pressure vessels utilized in a wide array of industrial applications, including those encountered at Mahathi Infra Services.

In conclusion, the effective and integrated utilization of these software tools significantly enhances design accuracy, reduces the overall design cycle time, and improves the safety and reliability of pressure vessel and piping systems, contributing to more efficient engineering practices within the industry.

IV. FUTURE DIRECTIONS

1) Enhanced Software Integration and Workflow Automation: Future research could investigate developing more seamless integration between design software such as PVElite, AutoCAD, and Caesar II (as utilized in this study and commonly employed in the oil and gas industry [based on the internship context]) and other engineering tools like Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) software. This enhanced interoperability could lead to greater automation of the design process, reducing manual input and the potential for errors, and ultimately improving overall efficiency in the design and analysis of pressure vessel and piping systems.
2) Leveraging Artificial Intelligence and Machine Learning for Design Optimization: The application of Artificial Intelligence (AI) and Machine Learning (ML) techniques could be explored to optimize design parameters, predict potential failure modes, and automate decision-making processes in pressure vessel and piping design. For example, AI algorithms could be trained to analyze large datasets of design and operational data from the oil and gas sector and similar industries to identify patterns and predict optimal design configurations, potentially leading to more efficient and safer systems.
3) Development and Utilization of Digital Twin Technology: A virtual counterpart of pressure vessel and piping systems, often referred to as a digital twin, could be developed and implemented. This technology would facilitate real-time monitoring, performance simulation, and optimization of these critical assets. Potential applications include predicting maintenance needs, optimizing operational parameters, and improving safety protocols across various industrial settings, including those encountered during the internship at Mahathi Infra Services.
4) Exploring Advanced Materials and Fabrication Techniques: Future studies might focus on incorporating advanced materials and manufacturing techniques into the construction of pressure vessels and piping. The aim would be to leverage options like composite materials, additive manufacturing (including 3D printing), and refined welding procedures to enhance the structural integrity, lifespan, and economic viability of these systems, potentially impacting fabrication processes observed during the shop-floor visit mentioned in the report.

V. CONCLUSION

A. *Caesar II Piping Stress Analysis*

1) The Caesar II software was utilized to design and analyze a section of pipelines for Mahathi Infra Services Uganda Ltd.
2) Initial analysis revealed varying displacement values at different nodes.
3) The stress intensity factor (SIF) was identified as a critical parameter for evaluation.
4) Design modifications, specifically the implementation of hangers, were employed to mitigate stress concentrations.

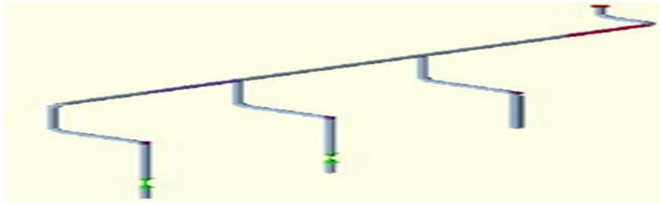
Node	Initial Displacement (mm)
Branch 1 (node 130)	0.5683
Branch 2 (node 180)	0.8210
Branch 3 (node 210)	1.0680

Fig 1. Table depicting initial displacement

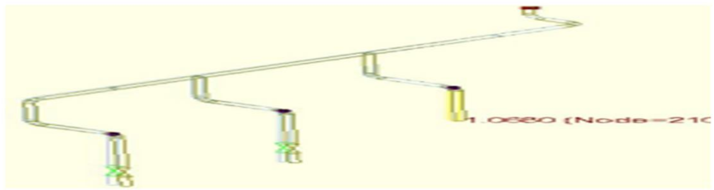
Parameter	Initial Value	Final Value
SIF at Critical Node	1.0680	0.860

Fig 2. SIF at Critical Node

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com



1.Before simulation



2.After Simulation

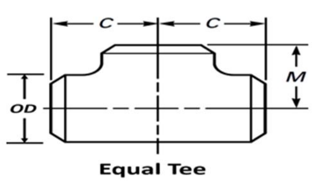
Fig3.Before And After Simulations

B. AutoCAD Sprinkler System Design

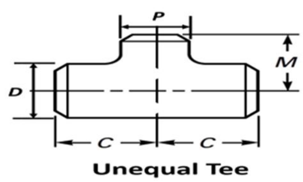
1) AutoCAD was used to develop designs for Zsprinkler systems.
2) The designs incorporated equal tee and reducing tee components.
3) Specific designs for "SPRINKLER RISER FOR 1LPM" and "SPRINKLER RISER FOR 3 LPM" were created.
4) Two design proposals were generated:

Design Feature	Design 1	Design 2
Support Structure	Angle IS 2850 at 45 degrees	Support at the top
Sprinkler Riser Capacity	1 LPM	3 LPM
Stability	Less stable	More stable
Key Components	Equal tee	Reducing Tees

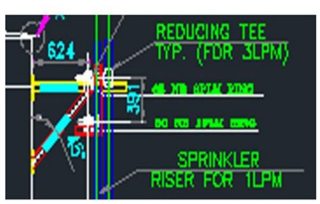
Fig 4.Two Design Equal tee and reducing tee



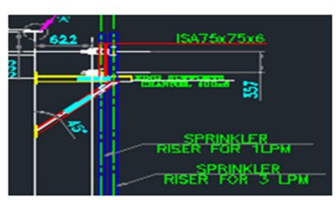
1.Equal tee description



2.Reducing tee description



1.Proposed Design 1



2.Proposed Design 2

Fig 5 : Diagrams showing both design

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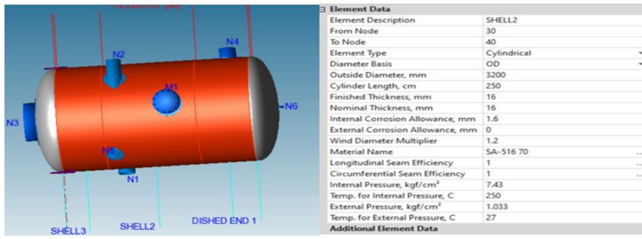

Fig6: Simulation of Pressure Vessel

C. PVElite Pressure Vessel Design

- PVElite was employed to design pressure vessels.
- The design process involved defining parameters such as shell dimensions and material properties.
- Components like SHELL2, DISHED END 1, and nozzles were included in the design.

Parameter	Value
SHELL2 Outside Diameter	3200 mm
SHELL2 Cylinder Length	250 cm
SHELL2 Finished Thickness	16 mm
SHELL2 Material	SA-516 70
Internal Design Pressure	7.43 kgf/cm²
Hydrostatic Test Pressure	12.456 kgf/cm²
Shell and Head Material	SA-516 70
Nozzle Material	SA-106 B
DISHED END 1 Element M.A.W.P	11.753 kgf/cm^2
SHELL2 Element M.A.W.P.	12.701 kgf/cm^2

Fig6: Showing Pressure vessel parameters

Key parameters of the pressure vessel design include: a SHELL2 with an Outside Diameter of 3200 mm, Cylinder Length of 250 cm, and Finished Thickness of 16 mm (Material: SA-516 70); an Internal Design Pressure of 7.43 kgf/cm²; and a Hydrostatic Test Pressure of 12.456 kgf/cm)

The Shell and Head are made of SA-516 70, while the Nozzle is SA-106 B. The Maximum Allowable Working Pressure (MAWP) is 11.753 kgf/cm² for DISHED END 1 and 12.701 kgf/cm² for SHELL2

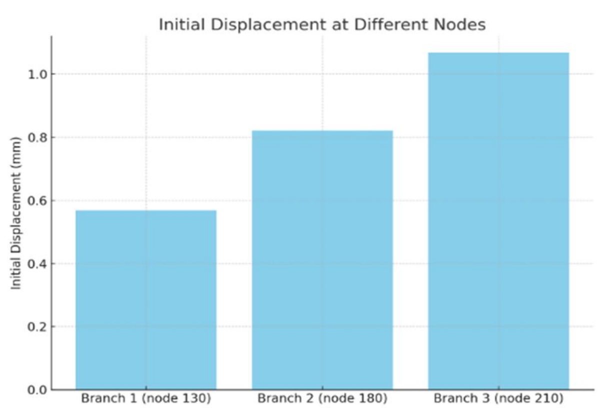

Fig7: Displacements at different nodes

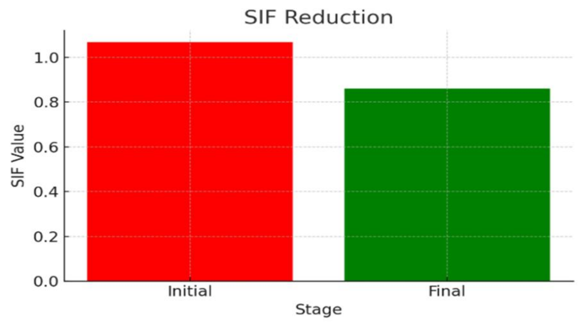

Fig 8: SIF Reduction Graph

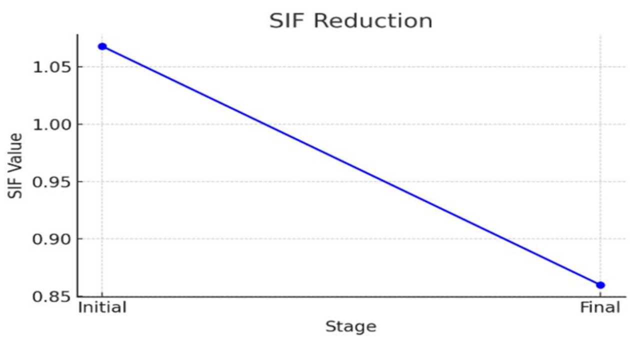

Fig 9: SIF Reduction Plot

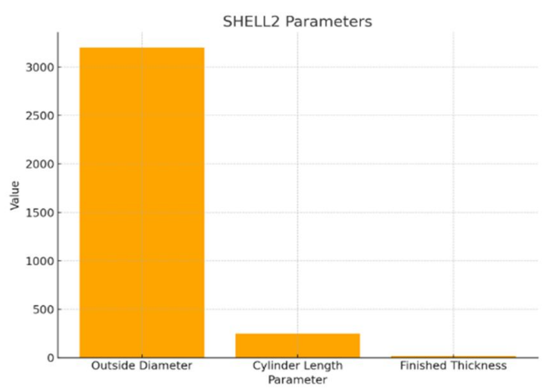

Fig 10: Pressure vessel parameters

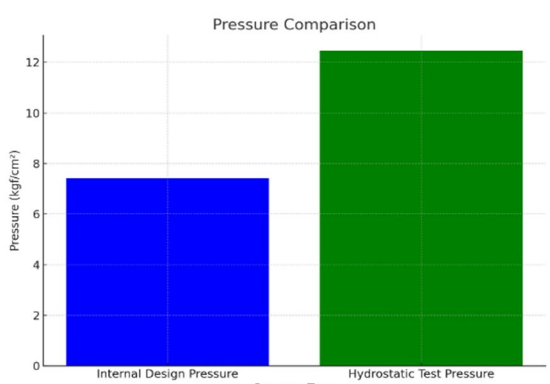

Fig 11: Pressure comparison

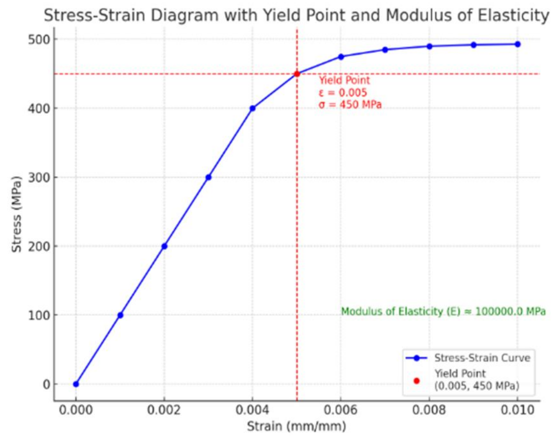

Fig 12: Stress Strain diagram for pressure vessels

VI. ACKNOWLEGEMENT

I would like to express my sincere gratitude to Executive Engineer Hyderabad Mr.D Obulesu Sir for giving me an opportunity to work on improving the drilling data operational efficiency.

I would also like to thank Dr. Sunil Kumar Ambast, Chairman, CGWB Ministry of Jal Shakti for giving me a chance to work in one of his vast divisions of India.

I am also indebted to Dr. Rishi Mohan Bhatnagar President AA2IT, my research guide, who has mentored me during my research accomplishments.

Grateful to all Staff, Technical, operator Drilling ,foreman and Junior Engineer for assisting me in day to day operations.

I am profoundly thankful for the unwavering guidance and mentorship of Dr. YVK Ravi Kumar and Prashant Joshi throughout my machine learning project. Their expert knowledge, consistent encouragement, and perceptive feedback have been indispensable to my development as a researcher.

Additionally, I would like to thank Prof. V. Ramgopal Rao Sir Vice chancellor and Dr Sudhir Kumar Barai Sir Director BITS PILANI for giving me opportunity to work as learning facilitator/guest faculty for the subject Conversational AI.

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