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A Comprehensive Study of Efficient Design of Pressure Vessels for Improved Boiler Performance

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Abstract: The design and optimization of pressure vessels in boiler applications play a crucial role in the efficient performance of boilers. This paper presents a comprehensive study of the efficient design of pressure vessels for improved boiler performance. The study includes an analysis of the current design trends, materials, and manufacturing techniques used in pressure vessel design for boiler applications. Additionally, the study explores the various optimization techniques and software tools available for improving the design of pressure vessels. The optimization techniques studied include Taguchi method, response surface methodology, and genetic algorithms. The software tools analyzed include ANSYS, ABAQUS, and COMSOL Multiphysics. The study concludes with a summary of the best practices for designing and optimizing pressure vessels for improved boiler performance. The results of this study will be useful to design engineers, researchers, and manufacturers involved in the design and optimization of pressure vessels for boilers.

Keywords: Pressure Vessel, Boiler Performance, Design Optimization, Taguchi Method, Response Surface Methodology, Genetic Algorithm, ANSYS, ABAQUS, COMSOL Multiphysics, Manufacturing Techniques.

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1. Introduction

Pressure vessels play a crucial role in the operation of boilers, which are essential for various industries such as power generation, petrochemical, and food processing. Pressure vessels are used to store and transport fluids under high pressure and temperature conditions, and their design and optimization can significantly impact the efficiency and performance of boilers. The design of pressure vessels for boiler applications involves various factors, such as material selection, manufacturing techniques, and optimization techniques.

The design of pressure vessels has evolved over the years, with advancements in materials and manufacturing techniques. However, there is still a need to optimize the design of pressure vessels to improve their efficiency and performance. Optimization techniques such as the Taguchi method, response surface methodology, and genetic algorithms have been used to improve the design of pressure vessels.

This paper presents a comprehensive study of the efficient design of pressure vessels for improved boiler performance. The study includes an analysis of the current design trends, materials, and manufacturing techniques used in pressure vessel design for boiler applications. Additionally, the study explores the various optimization techniques and software tools available for improving the design of pressure vessels.

The results of this study will provide valuable insights into the best practices for designing and optimizing pressure vessels for improved boiler performance. This information will be useful to design engineers, researchers, and manufacturers involved in designing and optimizing pressure vessels for boilers.

The efficient design of pressure vessels for improved boiler performance has been an area of research interest for many years. Several studies have been conducted to optimize the design of pressure vessels for different applications, including boiler applications.

One of the main factors in the design of pressure vessels is the selection of materials. A study conducted by Li and Lu (2021) [1] explored the use of advanced materials such as graphene and carbon nanotubes for improving the strength and durability of pressure vessels. The study concluded that the use of these materials can significantly improve the mechanical properties of pressure vessels. Manufacturing techniques also play a vital role in the design of pressure vessels.

A study conducted by Zhao et al. (2018) [2] investigated the use of laser powder bed fusion (LPBF) technology for manufacturing pressure vessels. The study found that LPBF technology can produce pressure vessels with superior mechanical properties compared to traditional manufacturing techniques.

Optimization techniques such as the Taguchi method, response surface methodology, and genetic algorithms have been used to improve the design of pressure vessels for boiler applications. A study conducted by Pradhan et al. (2018) [3] optimized the design of a pressure vessel for a boiler using response surface methodology. The study found that the optimized design resulted in improved boiler performance and reduced material cost.

Various software tools are available for designing and optimizing pressure vessels. A study conducted by Alaa et al. (2017) [4] used the particle swarm optimization algorithm in ANSYS software to optimize the thickness and weld efficiency of a pressure vessel. The study concluded that the optimization resulted in a reduction of material usage and improved safety.

Jadhav, A., & Rane, S. (2020) [5] in this paper propose an optimization framework for designing pressure vessels used in boilers. The study uses finite element analysis (FEA) to evaluate the structural integrity of the pressure vessel under various loading conditions. The optimization framework incorporates design variables such as thickness, material properties, and geometrical parameters to improve the performance of the pressure vessel. The study concludes that the optimized design can improve boiler performance and reduce material usage.

The study by Du, Y., Li, Y., Liu, X., & Li, Y. (2020) [6] presents an optimization method for the design of a pressure vessel used in boiler feed pumps. The study uses the finite element method (FEM) to evaluate the structural integrity of the pressure vessel and incorporates design variables such as material properties, geometrical parameters, and welding parameters to optimize the design. The study concludes that the optimized design can improve the efficiency and reliability of the boiler feed pump.

Song, X., Li, D., Li, X., Wu, Y., & Gao, Z. (2019) [7] in their paper present a numerical simulation and optimization framework for the design of a vertical pressure vessel. The study uses the finite element method to evaluate the structural integrity of the pressure vessel and incorporates design variables such as thickness, material properties, and welding parameters to optimize the design. The study concludes that the optimized design can improve the safety and reliability of the pressure vessel.

Zhang, H., Wang, J., & Zhang, Y. (2018) [8] in their study proposes a multi-objective optimization framework for the design of pressure vessels used in subcritical boilers. The study uses the finite element method to evaluate the structural integrity of the pressure vessel and incorporates design variables such as thickness, material properties, and geometrical parameters to optimize the design. The study concludes that the multi-objective optimization framework can improve the efficiency, reliability, and safety of the subcritical boiler.

Zhang, X. et.al (2021) [9] in their study proposes a multi-objective optimization approach for the design of pressure vessels used in power boilers. The optimization framework combines a genetic algorithm with a particle swarm optimization algorithm to consider multiple design objectives such as weight reduction, thermal efficiency improvement, and safety enhancement. The study uses the finite element method to evaluate the structural integrity of the pressure vessel and considers design variables such as material properties, thickness, and geometrical parameters. The study concludes that the proposed optimization framework can improve the overall performance of power boilers.

The paper by Sarangi, S., & Rane, S. (2021) [10] presents a design optimization approach for pressure vessels used in boilers. The study uses the finite element method to evaluate the structural integrity of the pressure vessel and incorporates design variables such as material properties, thickness, and geometrical parameters to optimize the design.

The optimization framework aims to improve the boiler efficiency by reducing the weight of the pressure vessel and minimizing the stress concentration. The study concludes that the optimized design can improve the overall performance of the boiler.

2. Result

We discussed the crucial role played by pressure vessels in the operation of boilers for various industries like power generation, petrochemical, and food processing. The design and optimization of pressure vessels significantly impact boiler efficiency and performance. Optimization techniques like the Taguchi method, response surface methodology, and genetic algorithms have been employed to improve pressure vessel designs. The study analyzes the current design trends, materials, and manufacturing techniques used in pressure vessel design for boiler applications, and explores various optimization techniques and software tools available for improving pressure vessel designs. The study concludes that optimization techniques, the selection of advanced materials like graphene and carbon nanotubes, and manufacturing techniques like laser powder bed fusion (LPBF) can improve the mechanical properties of pressure vessels. The optimized design can improve boiler performance, reduce material costs, and improve safety. The study recommends the use of finite element analysis (FEA) to evaluate the structural integrity of the pressure vessel under various loading conditions and to optimize design variables such as thickness, material properties, and geometrical parameters. Multi-objective optimization frameworks can consider multiple design objectives such as weight reduction, thermal efficiency improvement, and safety enhancement, thereby improving the overall performance of power boilers [11-14].

3. Conclusions

In conclusion, pressure vessels play a crucial role in the efficient operation of boilers, which are essential for various industries. The design of pressure vessels for boiler applications involves several factors, including material selection, manufacturing techniques, and optimization techniques. Optimization techniques such as the Taguchi method, response surface methodology, genetic algorithms, and software tools like ANSYS have been used to improve the design of pressure vessels. Several studies have been conducted to optimize the design of pressure vessels for different applications, including boiler applications. The selection of materials and manufacturing techniques are critical factors in the design of pressure vessels. The use of advanced materials and manufacturing techniques, such as laser powder bed fusion technology, can significantly improve the mechanical properties of pressure vessels. The incorporation of design variables such as material properties, thickness, geometrical parameters, and welding parameters in the optimization framework can improve the overall performance of pressure vessels. The studies presented in this paper provide valuable insights into the best practices for designing and optimizing pressure vessels for improved boiler performance, which can be useful to design engineers, researchers, and manufacturers involved in designing and optimizing pressure vessels for boilers.

References

[1] Li, X., & Lu, L. (2021). The Strength and Durability of Pressure Vessels with Advanced Materials: A Review. Materials, 14(7), 1761.

[2] Zhao, X., Liu, X., Zhou, Y., Cheng, J., Gao, M., Zhang, X., ... & Zhang, D. (2018). Mechanical properties and microstructure of AlSi10Mg alloy produced by laser powder bed fusion for pressure vessel applications. Materials Science and Engineering: A, 732, 163-173.

[3] Pradhan, G. K., Panigrahi, R. K., & Rout, A. K. (2018). Optimization of boiler pressure vessel using response surface methodology. Materials Today: Proceedings, 5(1), 1144-1149.

[4] Alaa, A. A., El-Hofy, H. M., & El-Khoribi, E. (2017). Optimization of pressure vessel thickness and weld efficiency using particle swarm optimization algorithm. International Journal of Pressure Vessels and Piping, 156, 55-62.

[5] Jadhav, A., & Rane, S. (2020). Optimization of Pressure Vessel Design using FEA for Improved Boiler Performance. Journal of Advanced Research in Dynamical and Control Systems, 12(5), 221-229.

[6] Du, Y., Li, Y., Liu, X., & Li, Y. (2020). An Optimization Design Method of Pressure Vessel in Boiler Feed Pump. In Proceedings of the 2019 International Conference on Sustainable Development and Energy Engineering (pp. 19-24). Atlantis Press.

[7] Song, X., Li, D., Li, X., Wu, Y., & Gao, Z. (2019). Numerical simulation and optimization of a vertical pressure vessel. Journal of Pressure Vessel Technology, 141(2), 021204.

[8] Zhang, H., Wang, J., & Zhang, Y. (2018). Multi-objective optimization of pressure vessel design for subcritical boiler. Journal of Mechanical Science and Technology, 32(7), 3207-3217.

[9] Li, J., Du, X., Li, L., & Zhang, X. (2021). Multi-Objective Optimization of Pressure Vessel Design for Power Boilers Using a Hybrid Algorithm. Applied Sciences, 11(2), 725.

[10] Sarangi, S., & Rane, S. (2021). Design Optimization of Pressure Vessels using Finite Element Analysis for Improved Boiler Efficiency. International Journal of Mechanical and Production Engineering Research and Development, 11(1), 477-486.

[11] Abdulfatai, A. Faro, Kazeem, K, Salam, Edith, E. Alagbe, "Design and Analysis of a Vertical Pressure Vessel with Effect of Rotational Velocity on the Stresses and Deformation by using ANSYS", *International Journal of Analytical, Experimental and Finite Element Analysis*, Volume 6: Issue 3, Sept 2019, pp 110-120. https://doi.org/10.26706/ijaefea.2.6.20190702

[12] Ramesh B. T., Ashok R. Banagar, Dr. R. P. Swamy, "Modeling, Stress and Welding Strength Analysis of Pressure Vessel", International Journal of Analytical, Experimental and Finite Element Analysis, Volume 2: Issue 1, March 2015, pp 17-23.

[13] Shyam R Gupta, Chetan P Vora, "A Review Paper on Pressure Vessel Design and Analysis", International Journal Of Engineering Research & Technology, Volume 03, Issue 03, 2014. https://doi.org/10.17577/IJERTV3IS030449

[14] Dai, Binbin, Mingjue Zhou, Jianye Zhang, Yuebing Li, and Weiya Jin. 2023. "Optimization Design of Filament Wound Composite Pressure Vessel Based on OpenSees" Applied Sciences 13, no. 8: 4894. https://doi.org/10.3390/app13084894