THE STUDY AND OPTIMUM DESIGN OF THE STRAINER PLATE IN THE FILTER TANK BY USING THE FINITE ELEMENT METHOD

Picha Panmongkol, Thaloeng Poljaroen*
Faculty of Engineering, Thonburi University, Nongkhaem, Bangkok, Thailand, 10160
*Corresponding author e-mail: thaloeng@thonburi-u.ac.th

Submitted: 29 November 2023
Revision received: 10 June 2024
Accepted: 11 Juner 2024

Abstract

This study focused on designing water strainer plates for producing water filter tanks in the industrial sector. The main issues included difficulties in manufacturing strainer plates and problems related to incomplete welding and inadequate painting of support strainer plates. To address these challenges, the project conducted an analysis using various tools to identify and solve problems. This project employed a finite element analysis method to design strainer plates that resolved the mentioned shortcomings. The result showed that the development of strainer plates using a flat bar type (Type-3) with a beam structure had the lowest displacement value, cut production time by 12% and material costs by 25%. This project could potentially elevate the industrial sector to produce water filter tanks, resolve the identified issues, and improve their manufacture.

Keywords: Simulation, Strainer plate, Finite element method, Filter tank, Pressure vessel

1. Introduction

A case study of M.P. Phan Ltd., Part. (1987) of the tank production process revealed problems with the strainer plate component in the manufacturing of pressure vessels, steel tanks, stainless steel tanks, mixing tanks, and water filtration tanks. The problem was analyzed using Why-Why Analysis, Fishbone Diagram Analysis, and Flow Process Analysis are shown in Fig. 1. It is a tool for brainstorming to find the cause of the defect to find a solution to the problem and propose a solution to the problem and action causes of the defect in the Table1. which revealed several key findings:

- Finding 1 revealed long production times due to the complexity of the process of strengthening the water filter.
- Finding 2 revealed problems from construction due to incomplete welding.
- Finding 3 revealed problems from construction with regards to the paintwork of the strainer plate that could not be painted thoroughly because the space under the strainer plate has a limited working area.

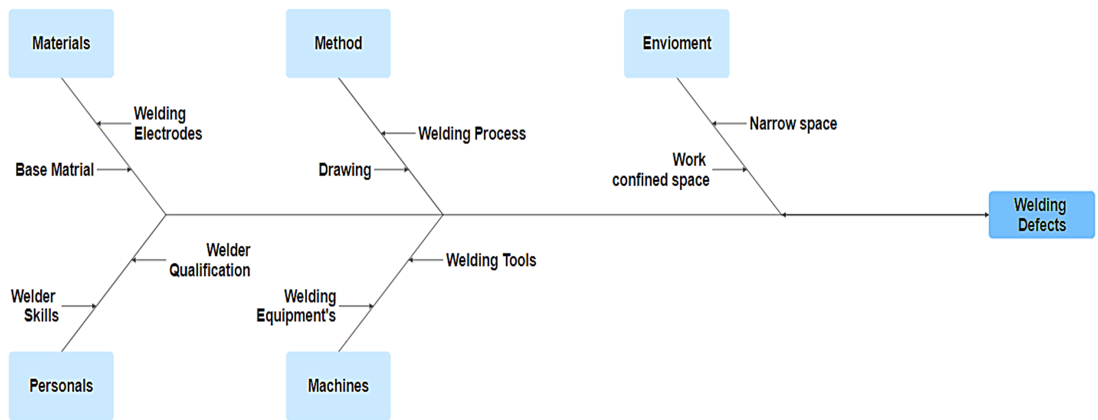

Figure 1 Cause and effect diagram of a welding defect

As shown in Figures 2 and 3, strainer plate paintwork must be revised frequently. Therefore, this research aims to study the design of the strainer plate used inside the water filter tank (Vicharnat, 2013.). The Finite Element Method (Gao, 2007.; Wang, 2011.; Cao, 2014.; V.N., 2006.; Li, 2014.) was used to design and simulate a strainer plate that is strong through production standards resulting in quicker production, reducing production steps while still producing quality products, and passing recognized production standards in the process of manufacturing water filter tanks. The organizing team, therefore, have produced a concept for the design of a water strainer plate to solve the identified problems. The results of this analysis and design have led to the actual production of strainer plates having a positive impact in the industrial sector.

Table 1 Propose a solution to the problem and action causes of the defect.

Cause	Recommended Action
Welding Electrodes and Base material	According to the WPS or project specification
Welder Skills and Qualification	Selected welder from WPQ (Exam. passed)
Drawing and Welding Process	Details of weld joints drawing
Welding Equipment and Tools	Preventive maintenance
Narrow space and work confined space	*New design of the supports of the water strainer plate

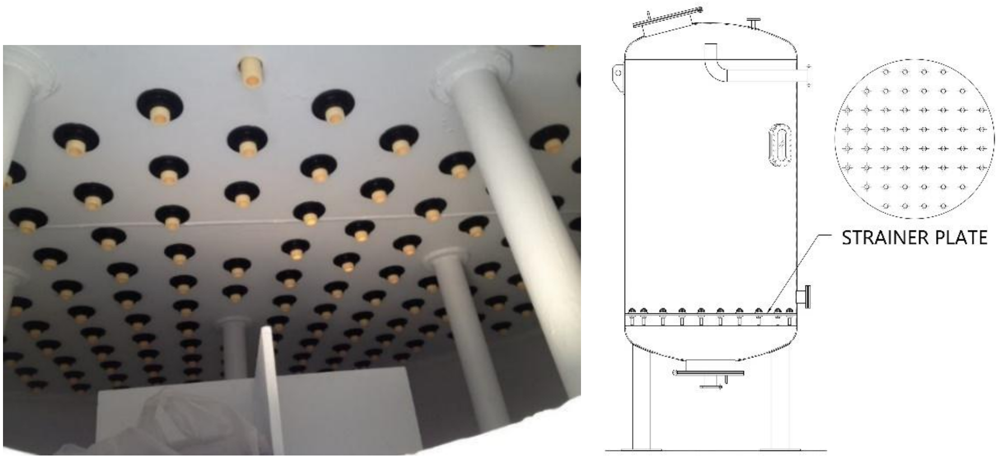

Figure 2 Strainer Plate

Figure 3 Defect Under the Strainer Plate

2. Research Objectives

The aim is to improve the strainer plate fabrication techniques used in industrial water filter tanks and achieve high-quality production. Creating an optimized, shortened production time and optimized cost strainer plate design involves addressing manufacturing challenges, incomplete welding, and paint defects using finite element analysis and other problem-solving techniques.

3. Research Methodology

3.1 Type of Strainer Plate Used in Experiments

In this study, the water filter tank had a diameter of 1,000 mm. and used ASTM A36 grade materials for construction. The designs of the strainer plate used in the experiment were divided into three types. Type 1: column type strainer plate (Fig. 4) with a thickness of 12 mm. and 4 pipe columns with sizes of 1-1/2 inches × length 300 × thickness 4 mm. This type of strainer plate is currently in traditional use. Type 2: thickening type strainer plate without reinforcing beams (Fig. 5) with a thickness of 20 mm. as a new alternative design approach. The design and calculations for the thickness of this type are described in the next section. Type 3: flat bar type strainer plate with beam structure (Fig. 6) with a thickness of 12 mm., assembled with two flat bars FB75 × 15, as another new alternative design approach. The strainer plate thicknesses used in the three experiments were written as 3D models from the Solid

Works program (Venkatachalam, 2016.; Wang, 2011.; Zang, 2013.) to analyze the strength and deformation values using the Finite Element Method. The components from the Solid Works simulation program (Chang, 2015.; Urdea, 2018.; Shinde, 2022.) for the strainer plate are shown in Figures 4-6.

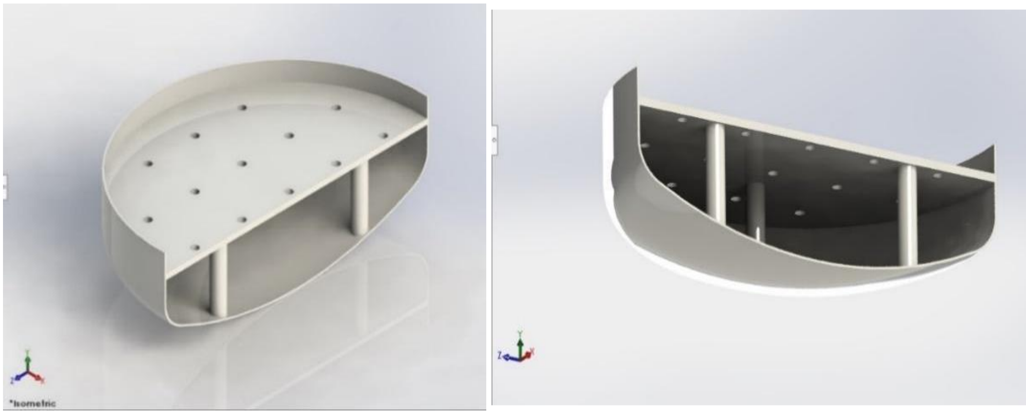

Figure 4 Strainer Plate; Column Type (Type 1)

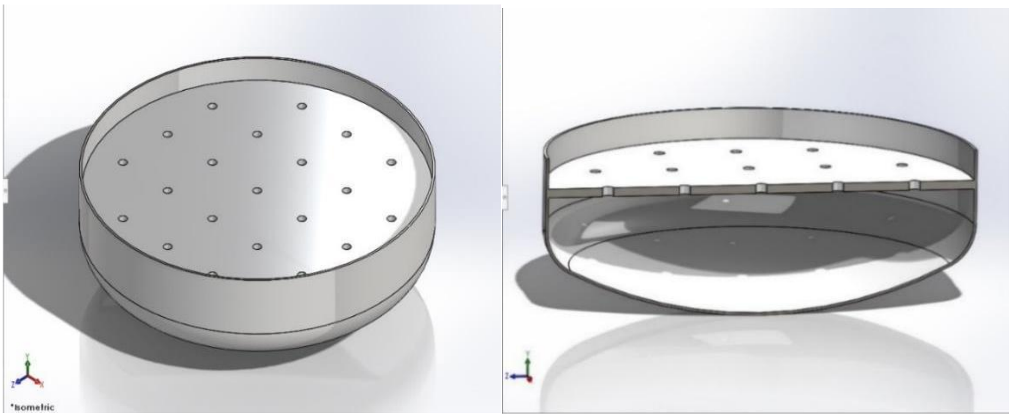

Figure 5 Strainer Plate; Thickening type (Type 2)

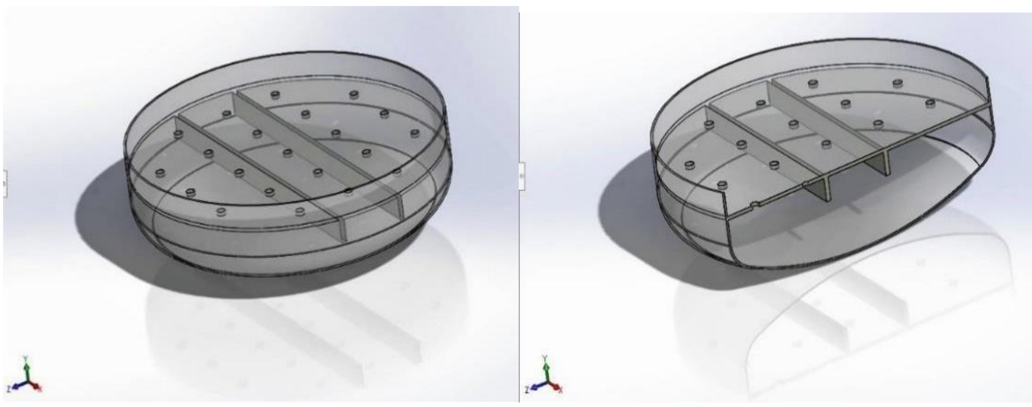

Figure 6 Strainer Plate; Flat Bar Type with Beams (Type 3)

3.2 Calculation of Strainer Plate Thickness Without Reinforced Beams (Type 2)

Calculation of the thickness of the Type 2-Thickening strainer plate (without reinforcing beams) was conducted according to the standard method outlined in ASME Section VIII Division 1 UG-34 C(2) [14]. According to Equation (1), the strainer plate thickness of Type 2 can be calculated from the following variables: t = thickness, d = diameter (1,000 mm), C = 0.33 (as in Figure 7), P = internal pressure (1 kg/cm^2), S = allowable stress of ASTM A36 grade material (1,167 kg/cm^2), E = Joint Efficiency, (1). From the calculation according to Equation (1), the minimum thickness is 16.8 mm., and the corrosion allowance is 1.5 mm (ASME, 2011.). This will obtain a minimum thickness of 18.3 mm.; we chose a thickness of 20 mm. as materials of this thickness can be found in the general market.

$$t = d\sqrt{CP/SE} \tag{1}$$

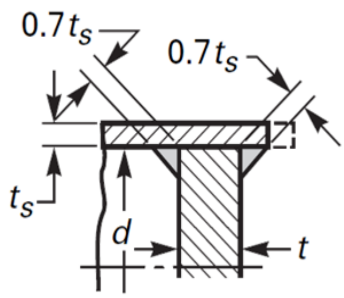

Figure 7 UG-34 Sketches Circular Covers, C = 0.33m

3.2 Finite Element Method (FEM)

Strength analysis of the 3D models, generated by the Solid Works simulation software (v2018) for each of the three strainer plate types, was performed using the Finite Element Analysis Method to determine static force as a case study to analyze stress (Von Mises Stress), deformation and displacement, and the safety value (Safety of Factor) that occurs with each type of strainer plate. The following steps were performed for analysis:

1. Set the properties of the Static Analysis, 2. Determine the properties of the workpiece material. (Applied Material) ASTM A36, 3. Set fixed variables such as the geometry of the tank wall and body as well as a solid composition and solid body type of the components. This condition of Fixed Geometry the actual installation is shown in Figure 8(A). The model and the physical strainer plate are fabricated using ASTM A36 Steel, known for its 3,314.08 kg/cm^2 yield strength and 7,870 kg/m^3 mass density. Acting on the strainer plate in the filter section, a perpendicular force of 1 kgf/cm2 is applied. The model considers the earth's gravity to be applied to be 9.81 m/s^2, as shown in Figure 8(B). The analysis type is set to static, and a standard solid mesh is applied, utilizing four Jacobian points and an element size of 21.9, 21.5, and 22.2 mm, respectively. The tolerance is configured at 1.09, 1.07, and 1.11 mm, respectively. The mesh quality plot indicates the high quality. The model is comprised of 72,843, 65,849, and 65,452 nodes and 38,558, 33,752, 32,870 elements, respectively, and the maximum aspect ratio is 29.9, 17.5, and 18.8, respectively, the created mesh was shown in Figure 8(C). The program automatically executes the processing after the element decomposition is completed and displays the results of the model's calculations in colored bands.

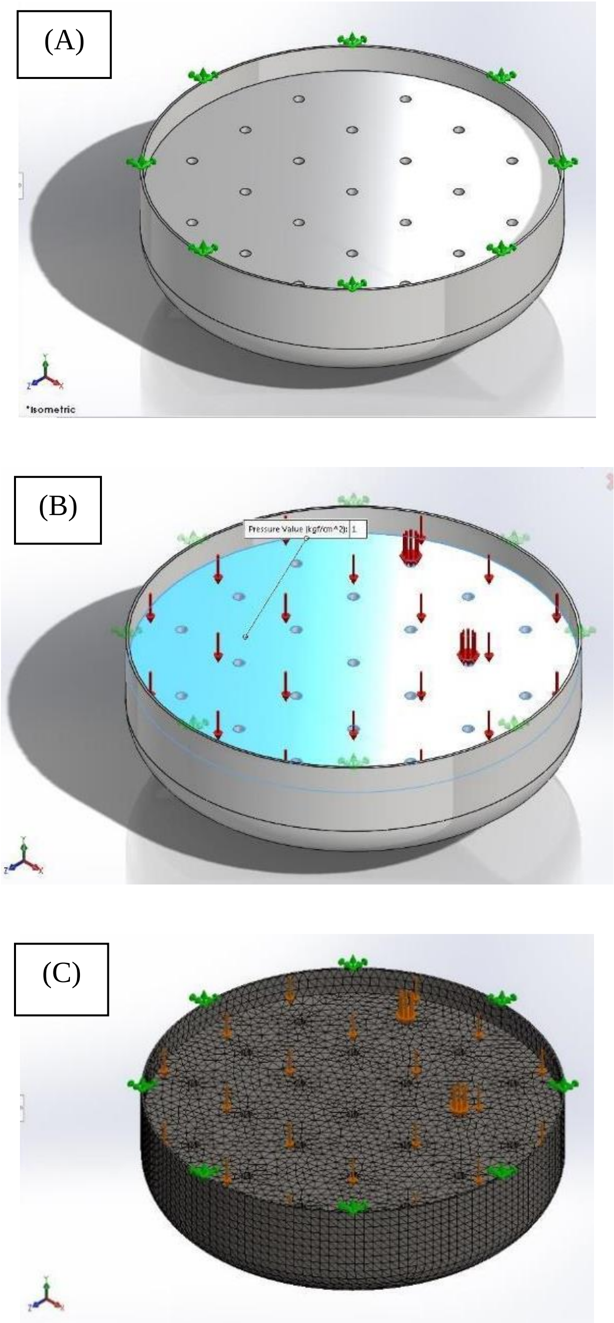

Figure 8 (A) Fixed Geometry, (B) Pressure, and (C) Create Mesh.

3. Results and discussion

The experiment results obtained from the Solid Works simulation software include, for each type of strainer plate, values for stress (Von Mises Stress), deformation (displacement), and safety (Safety of Factor). These results are summarized in Table 2.

For the Type 1-Column type strainer plate, it was found that maximum stress occurred at the area of support and the tank lid with a force of 1,182 kgf/cm^2, and maximum deformation occurred at the center of the strainer plate with a value of 0.89 mm, as shown in Figure 9. For the Type 2-Thickening type strainer plate, results showed that the strainer plate's maximum stress occurred at the tank wall with a force of 919 kgf/cm^2 and the maximum deformation occurred at the center of the strainer plate with a value of 1.41 mm, as shown in Figure 10. For Type 3- Flat bar type strainer plate with beam structure, results showed that the maximum stress occurred at the beam under the strainer plate with a force of 1,189 kgf/cm^2 and the maximum deformation occurred at the center of the strainer plate with a value of 0.60 mm, as shown in Figure 11. In analyzing the experiment results, it was found that the highest stress force that occurs in all three types of strainer plates does not exceed the yield strength of 2549.29 Kgf/cm^2, indicating that the plates could bear safe loads; the deformation value was highest at the center point of the Type 2-Thickening type strainer plate and the lowest deformation value was in the Type 3-Flat bar type strainer plate with beam structure.

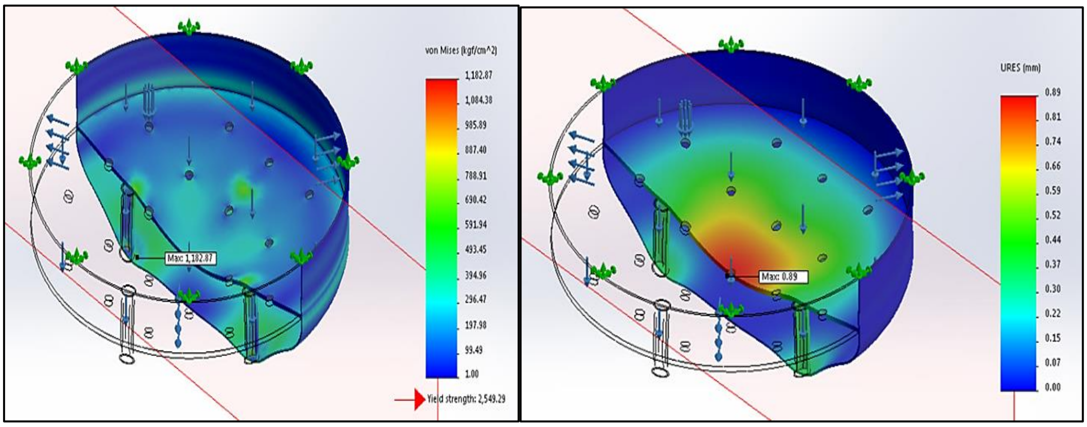

Figure 9 Type 1-Column Type; Von Mises Stress (Left) and Displacement (Right)

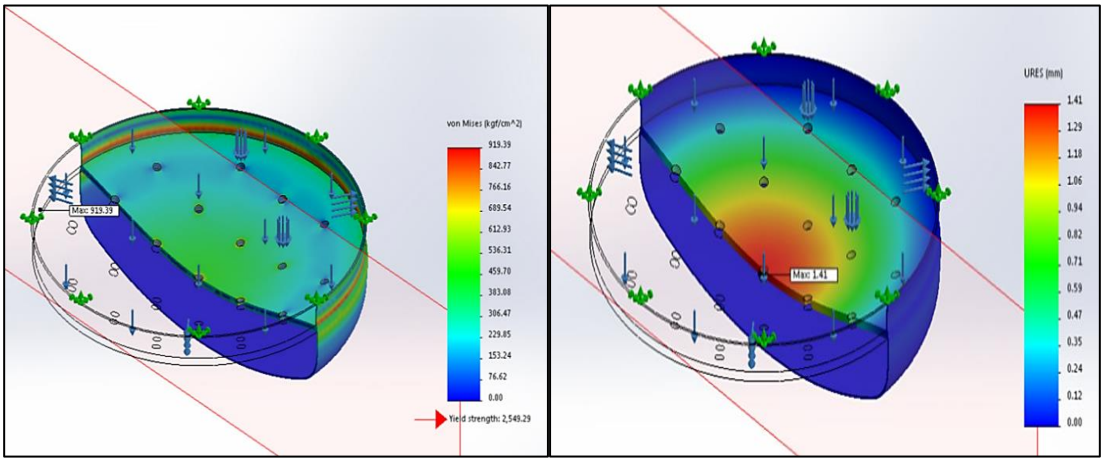

Figure 10 Type 2-Thickening Type; Von Mises Stress (Left) and Displacement (Right)

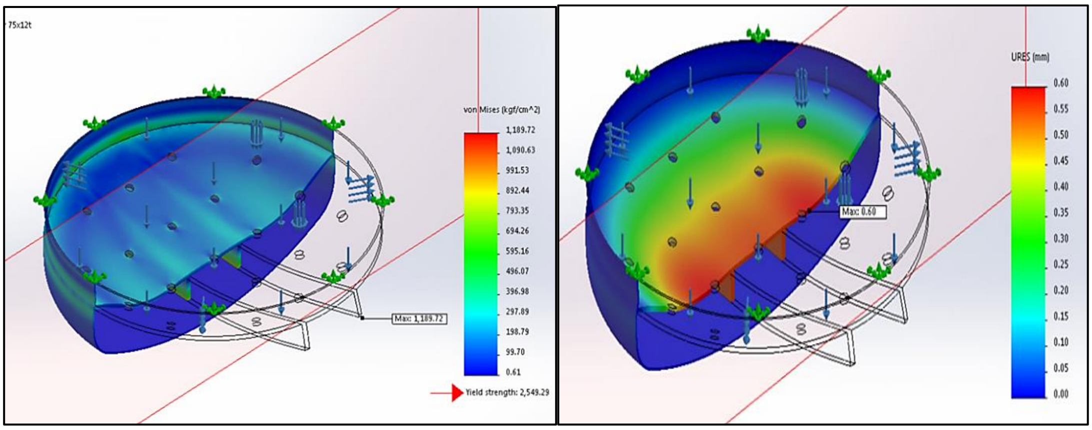

Figure 11 Type 3-Flat Bar Type with Beams; Von Mises Stress (Left) and Displacement (Right)

Table 2 Summary of Experiment Results

Strainer Plate	**Von Mises Stress (Kgf/cm^2)**	**Displacement (mm)**	**Factor of Safety**
Type 1-Column type	1,182	0.89	2.16
Type 2-Thickening type	919	1.41	2.78
Type 3- Flat bar type with beams	1,189	0.60	2.14

The experiment results, as seen in Table 2, showed high stress force on the Type 1 strainer plate and Type 3 strainer plate; it was found that the p-value was equal to 0.51, greater than the alpha level of 0.05 (p-value > 0.05). There was no significant difference at 95% confidence and the Type 2 strainer plate had the least occurring maximum stress. When considering the effect of the deformation value, it was found that the Type 2 strainer plate had the highest deformation value. This may be attributed to the fact that there is no support point to help strengthen the strainer plate. From the experiment results of the safety values on the test specimen using one-way ANOVA analysis, it was found that maximum stress was on the Type 1 strainer plate and Type 3 strainer plate with the p-value equal to 0.25, greater than the alpha level of 0.05 ($p\text{-value} > 0.05$).

The process involves implementing improvement guidelines through meetings with pertinent production process working groups, conducting improvement trials with a focus on the production process, and maintaining ongoing monitoring of operations. Therefore, evidence suggests that the Type 3 strainer plate is safe to use and can be applied for use in real production in the industrial sector to create water filtration tanks (Figure 12).

Fig. 12 Type 3- Flat Bar Type with Beams Used in Real Production in the Industrial Sector

However, the results indicate that the Type 2-Thickening type has a material weight of 200 kilograms, while the Type 3-Flat bar type with beams has a material weight of 150 kilograms; this represents a 25% reduction in material weight costs. When comparing the production time of the Type 1-Column type with Type 2-Thickening type using 33 working days compared to the Type 3-Flat bar type with beams using 29 working days, the results show that the production time was reduced by 12%.

5. Conclusion

Using the Finite Element Analysis Method on all three models, the maximum stress (Von Mises Stress) force, deformation value, and safety value were computed for each of the three types of strainer plates. The Type 3 strainer plate, with the beam structure, was determined to be the optimal new alternative design approach for strainer plates, with a minimal deformation value and reasonable maximum stress force and safety values. The experiment results showed that there was not a significant difference in the computed values between the traditional Type 1 strainer plate and the alternative design of the Type 3 strainer plate, used in the production of water filter tanks. There is evidence from the experiment and real applications that the Type 3 strainer plate can reduce cost in materials by 25%, help avoid messy work, and allow faster production times due to the area under the strainer plate being much more sufficient for work. These solutions can lead to better work quality and quicker delivery. The production time was reduced by 12%. The Type 3 strainer plate can be readily applied in the industrial sector, producing strainer plates of high quality that still pass production standards for the manufacturing of water filter tanks.

6. Acknowledgment

Mr. Naris Sonprapai and Mr.Khet Burakorn, M.P. Phan (1987) Ltd., Part. and AEC INDUSTRIAL SERVICES Co., Ltd. Support data and software for the study of this project. The authors thank Mr. Josh Beatty for reviewing and proofreading the paper for grammatical accuracy.

7. References

ASME. (2011). **The American Society of Mechanical Engineers Boiler & Pressure Vessel Committee on Pressure Vessels Section VIII Division** (1st ed.). Addenda 2011a.

Cao, X.J., & Miao, D.H. (2014). Research the Application of Elliptic Filter Plate to Horizontal Filtering Tank. **Advanced Materials Research**, 1004-1005, 1275–1280.

Chang, K.H. (2015). **Design Optimization**. Massachusetts: Academic Press. Doi: 10.1016/b978-0-12-382038-9.00017-x

Gao, B.J., Shi, X.P., Liu, H.Y., & Li, J.H. (2007). Separation of Primary Stress in Finite Element Analysis of Pressure Vessel with the Principle of Superposition. **Key Engineering Materials**, 353-358, 373–376.

Li, W.J., Liu, G.P., Li, D.H., & Yu,T. (2014). Finite Element Analysis and Optimum Design for Pressure Vessel Based on ANSYS Workbench. **Applied Mechanics and Materials**, 687-691, 290–293. Doi: 10.4028/www.scientific.net/AMM.687-691.290

Shinde, J., Kharade, S., Mulani, A., Kokare, K., Tapase, C., & Terani, A. (2022). Design and analysis of front axle using Solidworks simulation. **International Research Journal of Engineering and Technology (IRJET)**, 9(5), 3477-3483.

Skopinskyand, V.N., & Smetankin, A.B. (2006). Modelling and Stress analysis of nozzle connections in Ellipsoidal heads of Pressure vessels under External loading. **International Journal of Applied Mechanics and Engineering**, 11(4), 965- 979.

Urdea, M. (2018). **Static linear analysis for trusses structure for supporting pipes**. IOP Conference Series: Materials Science and Engineering. Doi: 10.1088/1757-899X/399/1/012051

Venkatachalam, G., Nishanth, J., Mukesh, M., & Pavan Kumar, D.S. (2016). Investigations on Influence of Geometric Parameters in Drawing of Perforated Sheet Metals. **Applied Mechanics and Materials**, 852, 229–235.

Vicharnat, P. (2013, May). **Study and Design of Pressure Vessel Thickness and Anthracite Filter Tray in the Pressure Vessel Using Finite Element Method**. RSU Research Conference 2013, Sangsit University, Bangkok.

Wang, J., Huang, X.Y., & Sang, S.J. (2011). Using Multiple Methods for Rapid Programming in SolidWorks. **Applied Mechanics and Materials**, 48-49, 1337–1340.

Wang, W., Shi, J.B., Luo, M.F., Wang, Y.F. (2011). Study on a Large Opening in a Pressure Vessel. **Advanced Materials Research**, 308-310, 58–61.

Zhang, C.L., & Yang, F. (2011). Pressure Vessel Optimization Design Based on the Finite Element Analysis. **Applied Mechanics and Materials**, 65, 281–284. Doi: 10.4028/www.scientific.net/AMM.65.281

Zhang, J. (2013**). EFD Fluid Simulation of Ball Valve on SolidWorks. Advanced Materials Research**, 823, 13–16.