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Redesign of a Pressure Vessel for Operation at 1.71 MPa

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***Abstract* - Pressure vessel is a liquid or solid fluid container made using metal materials with pressure in it. Pressure vessels also have a variety of shapes, which generally include horizontal, vertical, and spherical pressure vessels. The components of pressure vessels include top head, bottom head, shell, and nozzle. This study aims to obtain the geometry value of the pressure vessel which will be made geometry modeling that will be evaluated stress distribution, buckling, personal frequency, wind load so that the results will be obtained which can later be used as a design reference. This pressure vessel has a pressure of 1.71 MPa and has an operating weight of 16,698 kg, with a height of 6,539 mm and a diameter of 2,250 mm which will be installed in the Ujung Pangkah gas field Gresik, East Java, Indonesia. The pressure vessel will be used to develop the Ujung Pangkah oil and gas reserves by exporting gas to the power plant in Gresik after onshore separation and processing. The oil will be processed, stored and exported by bulk tanker. This research method includes literature study, data collection and processing carried out during the internship, after which geometry modeling using solidworks software and FEM analysis using ansys software. The results of this report find that the design of the pressure vessel is in accordance with the ASMESec.VII Div. 1 and has been validated using FEM analysis using ansys.**

Keywords: Buckling, Natural Frequency, Pressure vessel, Stress, Wind Load.

I. INTRODUCTION

Pressure vessel is a container that serves to store pressurized fluid, be it liquid or gas. In designing pressure vessels for industrial use, it is necessary to consider the various stresses that appear on the walls. These stresses can be caused by external factors, such as wind and earthquake loads, as well as internal factors derived from the working pressure and weight of the vessel itself [1]. Pressure vessels are used in a variety of applications in the industrial sector, including the chemical industry, energy generation, oil and gas, and the nuclear industry [2].

Pressure vessels play an important role for pressurized fluid containment [3]. Fluids stored in pressure vessels usually have special characteristics, such as pressurized fluids, fluids with low or high temperatures, and others [4]. One of the important processes in producing quality oil and gas is the refining process. In the refining process, a pressure vessel is needed that will accommodate and separate the particles contained in the oil before distribution. The pressure vessel will experience pressure from the petroleum and gas it holds [5].

Pressure vessels have a complex geometric structure with various discontinuities, and are generally designed to operate under high loading conditions, such as external forces, thermal loads, internal pressure, etc. [6]. Therefore, in this study the authors chose the title "Pressure Vessel Redesign with a Pressure of 1.71 MPa" where the data used comes from PT Timas Suplindo with CFU Vessel code 742-V-001 when the author did his internship. Which later this pressure vessel will be installed in Ujung Pangkah gas field located off the north coast of East Java about 35km north of Gresik, East Java, Indonesia.

It is planned that the pressure vessel will be used to develop the Ujung Pangkah oil and gas reserves by exporting gas to the power plant in Gresik after onshore separation and processing. The oil will be processed, stored and exported by bulk tanker. This research is used to deepen the understanding of pressure vessel redesign using ASME Sec. VIII Div.1 standard and to evaluate the pressure vessel design using Ansys software.

II. MATERIALS AND METHODS OF RESEARCH

2.1 Geometry Shaping

At this stage calculations will be carried out to determine the geometry in accordance with ASME Sec. VIII Div.1 standards. As for after doing the calculations shown in the following attachment geometry data used.

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Table 1: Thickness & MAWP

Nama Part	*Thickness* (mm)	MAWP (Mpa)
Top Head	20	2.1066 MPa
Bottom Head	20	2.107
Shell	20	2.427
Nozzle MH 1 & MH 2	20	9.21
Nozzle HH1	12.7	11.3988
Nozzle HH1	12.7	11.3988
Nozzle N1 & N2	12.7	14.34479
Nozzle N3 & N4	12.7	14.34479
Nozzle N6	11.13	32.81053
Nozzle N7	11.13	32.81053
Nozzle N5	11.13	32.81053
Nozzle N10, N11B, N12A, N13A	8.74	38.6349
Nozzle N11A & N14	8.74	38.6349

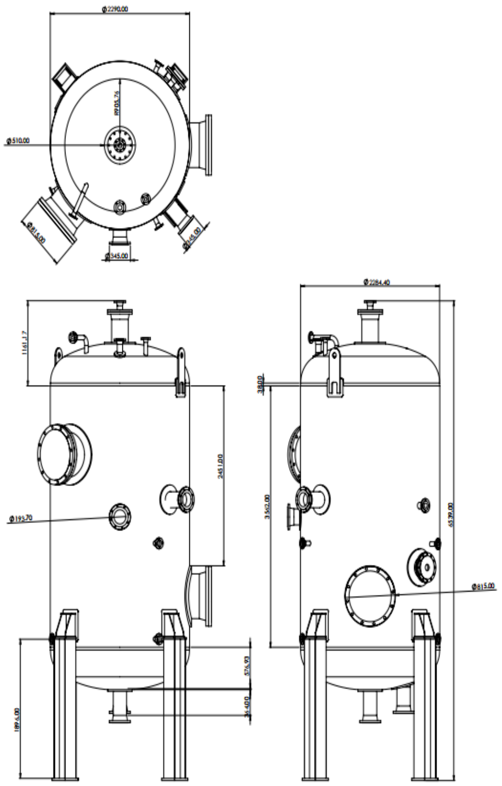

Figure 1: Pressure Vessel Geometry

2.2 Material selection

Material selection is one of the important processes in a tool design. The materials used must be in accordance with the design standards that have been determined and ergonomic.

Table 2: Material Specification

Nama *Part*	Material
Shell	SA-516 Gr.70
Ellips head	SA-516 Gr.70
Reinf. pad	SA-516 Gr.70
Liftinf lugs	SA-285 Gr.C
Support legs	SA-285 Gr.C
Nozzle MH 1 & MH 2 (24")	SA-516 Gr.70
Nozzle HH1 & HH2 (10")	SA-106 Gr.B
Nozzle N1 & N2 (8")	SA-106 Gr.B
Nozzle N3 & N4 (8")	SA-106 Gr.B
Nozzle N6 (3")	SA-106 Gr.B
Nozzle N7 (3")	SA-106 Gr.B
Nozzle N5 (3")	SA-106 Gr.B
Nozzle N10,N11B,N12A,N13A (2")	SA-106 Gr.B
Nozzle N10,N11B,N12A,N13A (2")	SA-106 Gr.B

2.3 Meshing

Meshing is a technique used to divide the object to be simulated into small elements [7]. In the mesh generation process using Ansys Meshing, the main goal is to achieve a mesh with low skewness to ensure accurate simulation results and good convergence. Skewness has a range of values from 0 to 1, with lower values indicating better mesh quality [8]. The meshing results in this study resulted in a skewness value of 0.93923 Table 3 shows the mesh quality standard used in Ansys. Based on the skewness value obtained, the mesh quality is categorized as acceptable.

Table 3: Skewness Meshing

Excellent	Very Good	Good	Acceptable	Bad	Unacceptable
0-0.25	0.25-0.50	0.50-0.80	0.80-0.94	0.95-0.97	0.98-1.00

III. RESULTS AND DISCUSSIONS

3.1 Convergence Testing

Convergence testing is an analytical process used to determine whether the numerical solution of a problem will approach its true value as the number of elements in the mesh or grid increases. In the context of the finite element method (FEM), convergence occurs when the calculation results become stable or change very little despite the increasing number of elements used. This process is performed on the geometry and maximum stress value of each element.

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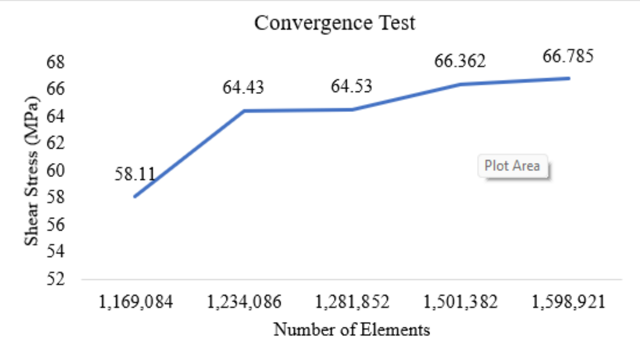

Figure 2: Convergence Test

3.2 Stress Analysis of Pressure Vessels

The data obtained from stress analysis conducted using Ansys software is divided into several parts. From the simulation results carried out on the pressure vessel, various data are obtained that can be a reference before the production process of the CFU101-V-521 pressure vessel. For the total deformation obtained with a max value of 6.92 mm and a minimum of 0 mm.

Shear stress is the stress that occurs when a force is applied parallel or tangential to the surface of the material. This is in contrast to normal stress, which occurs when a force is applied perpendicular to the surface. Based on the shear stress simulation results, the maximum value is obtained at 66.785 MPa.

In the stress analysis simulation results, a safety factor value of 3.565 was obtained. Where in the context of pressure vessel design, the minimum safety factor of ASME Sec VIII Div 1 is 3.5. Thus, the simulation results show that the safety factor has been met and exceeds the requirements set by ASME Sec. VIII Div 1. This indicates that the pressure vessel analyzed has been designed in accordance with applicable safety standards.

Table 4: Simulation Results Stress Analysis

Parameter	Minimum	Maximum	Average
Total Deformation	0 mm	6.92 mm	4.102 mm
Shear Stress	8.39E-05 MPa	66.785 MPa	7.7631 MPa
Safety factor	3.545	15	14.803

3.3 Buckling

Buckling is the phenomenon of sudden change in shape or deformation in a structure due to load. Here we will discuss the results of buckling simulations using Ansys software. The output that will be generated is an eigenvalue of 3.7622 where the eigenvalue value is higher than the safety factor, indicating that the pressure vessel has a much higher buckling capacity, indicating that the pressure vessel structure has a fairly good margin against buckling.

3.4 Natural Frequency

Natural frequency simulation results using Ansys software produce output values of natural frequency. The following are the simulation results and some of the resulting shape modes. The natural frequency value generated in shape mode 1 is 11. 642 Hz, shape mode 2 is 11.86 Hz and shape mode 3 is 26.502 Hz.

3.5 Wind Load

This section discusses wind load analysis in the design of pressure vessel structures using Ansys software. Wind load is one of the significant natural loads in design, especially in areas with extreme wind conditions. Therefore, the wind load at the installation site of the pressure vessel is 23.4 m/s. The results of the simulations that have been carried out using Ansys fluent software with an air density of 1,225 kg/m3 obtained the maximum pressure value generated of 442,121 Pa.

IV. CONCLUSION

Based on this research, it is found that the pressure vessel has met the ASME Section VIII Div.1 standard, for the simulation results the total deformation gets a maximum value of 6.92 mm, while for the maximum shear stress can be said to be safe because it is still below the yield strength and safety factor of 3.545. Where in the context of pressure vessel design, the minimum safety factor from ASME Sec VIII Div 1 is 3.5. The resulting eigenvalue is higher than the safety factor, indicating that the pressure vessel has a much higher buckling capacity and has a significant safety margin against buckling, while for the natural frequency, 11.642 Hz is obtained, where the average earthquake in Indonesia ranges from 5-6 Hz and for the wind load, the maximum pressure value generated is 442.121 Pa.

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