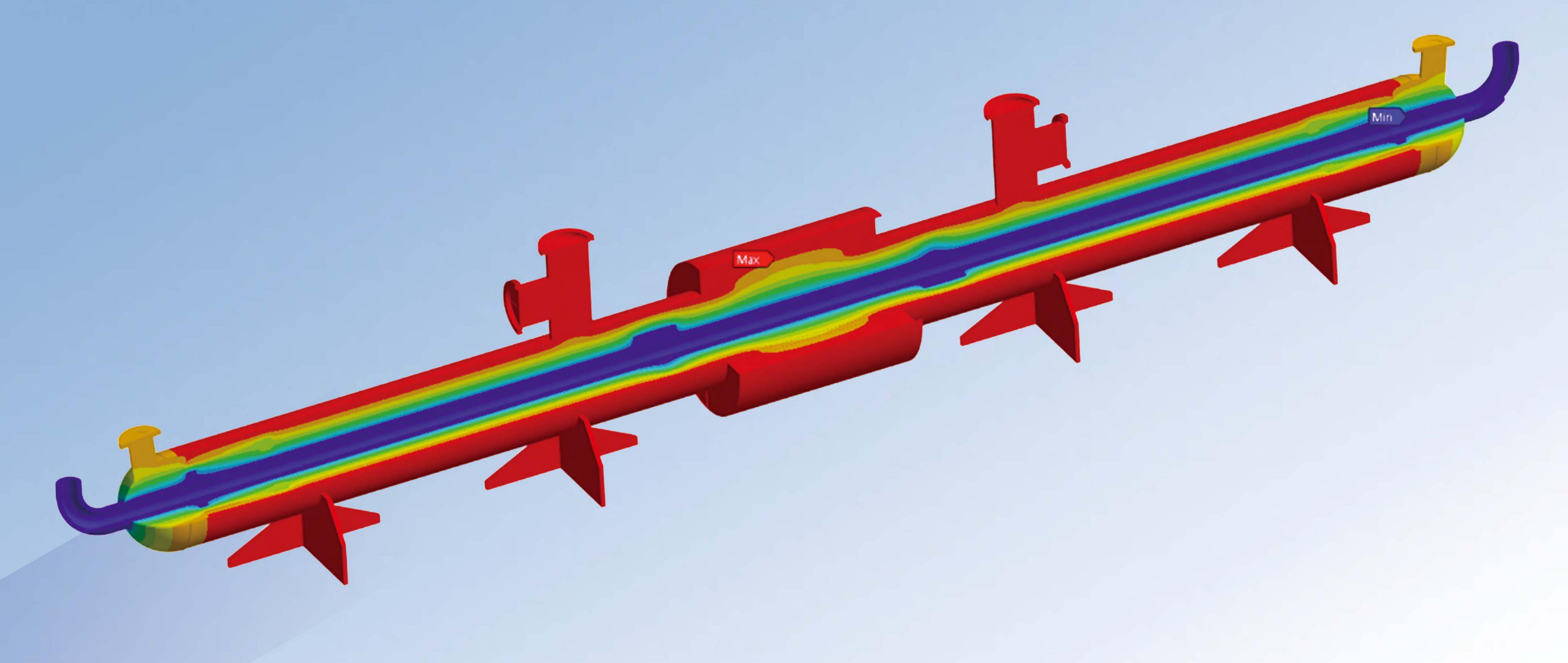


PROJECT WORK REPORT

Vacum Insulated Pipe

Development of Manufacturing Technology for Cryogenic Double Insulation Pipes





SEHO ENGINEERING Co., Ltd.

Ulsan City, South Korea







Thermal & Structural Analysis of Vacuum Insulated Pipe

This project is carried out to develop a low-temperature gas transfer tube including vacuum insulation, and examines the appropriate thickness of the inner pipe and the outer pipe according to the cryogenic fluid inside the test device and the appropriate thickness of the insulation.

When unloading gas cargo or sending gas through pipes to cold storage facilities, the pipes where the gas flows pass through must have their own thermal insulation Because it can prevent gas from expanding or disappearing.

(Deokcheon Co., Ltd. is to develop a test device by verifying the thermal insulation effect of Vacuum Insulated Pipe, and Seho Engineering Co., Ltd. is to verify the product by preliminary review and numerical analysis of the test device.

Project Period

2022.06 ~ 2023.12

Scope of Work

- Numerical Analysis of Vacuum Insulated Pipe
- Technical review of the low temperature characteristic of the test model through numerical analysis of the Vacuum Insulated Pipe test device

Vacuum Insulated Pipe

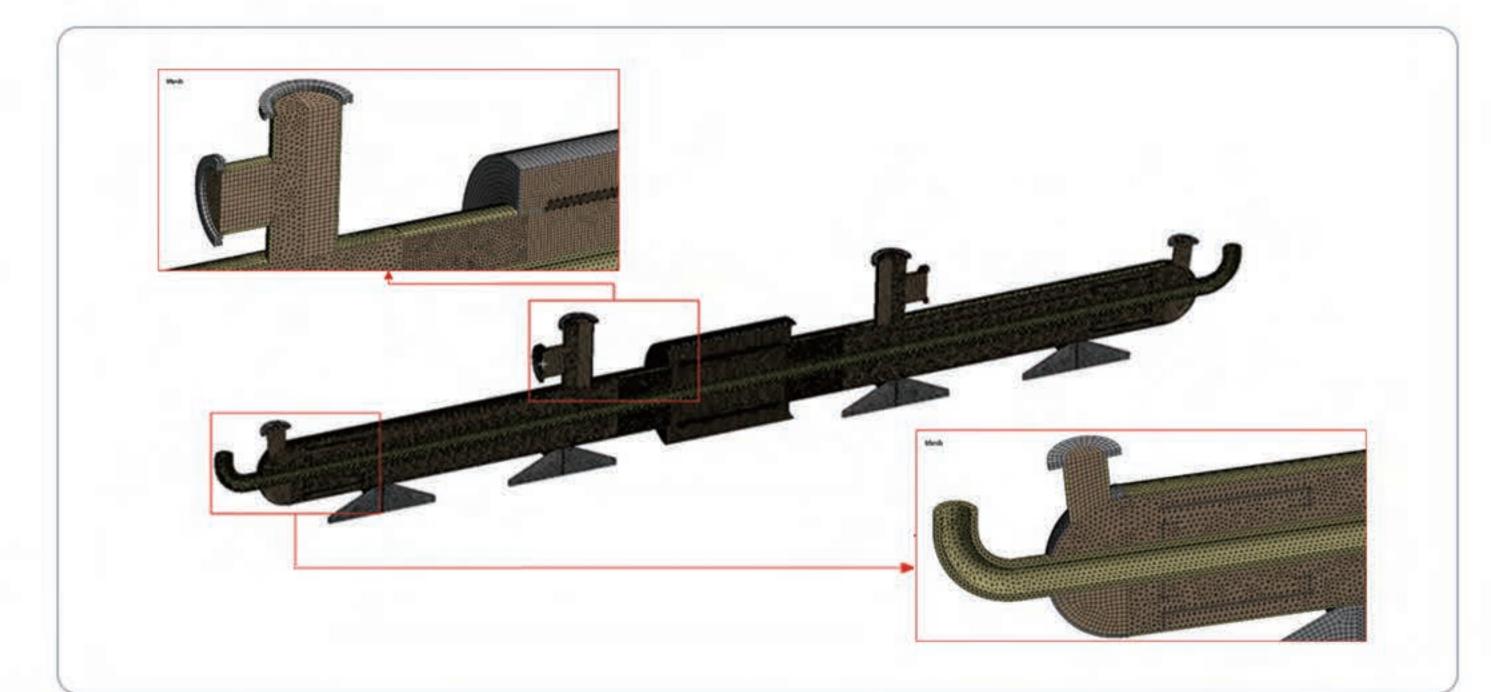
The Vacuum Insulated Pipe test device, the Inner Pipe is End Support at both ends and Flexible Support and installed on the Outer Pipe. Bellows installed in the middle of the outer pipe are It is responsible for correcting the difference in displacement due to heat shrinkage of the outer pipe exposed to the outside air (20°C room temperature) of the inner pipe at -196°C. In addition, a bellows cover is installed to prevent heat from leaking directly from the thin bellows to the outside.

Structural Analysis

Specification

| | 주요성능 (Constitution) Unit | | Development Target | | | |
|---|-----------------------------|--------|----------------------|----------------------|----------------|--|
| | (Specification) | Offic | 1 year (Perlite+진공) | 2 year (MLI+진공) | 비고 | |
| 1 | Shell Strength | Bar | ≤ 380 | ≤ 480 | ASME B31.3 | |
| 2 | Leak Test | cc/min | ≤ 0.01 | ≤ 0.01 | | |
| 3 | Vacuum Test | Torr | 5*10 ⁻³ ≤ | 5*10 ⁻⁴ ≤ | 공인 기관 시험 | |
| 4 | Heat Leak | W/ft | ≤ 0.6 | ≤ 0.45 | | |
| 5 | BOG | % | ≤ 0.5 | ≤ 0.3 | | |

FE Model



FE Mesh and Element Types

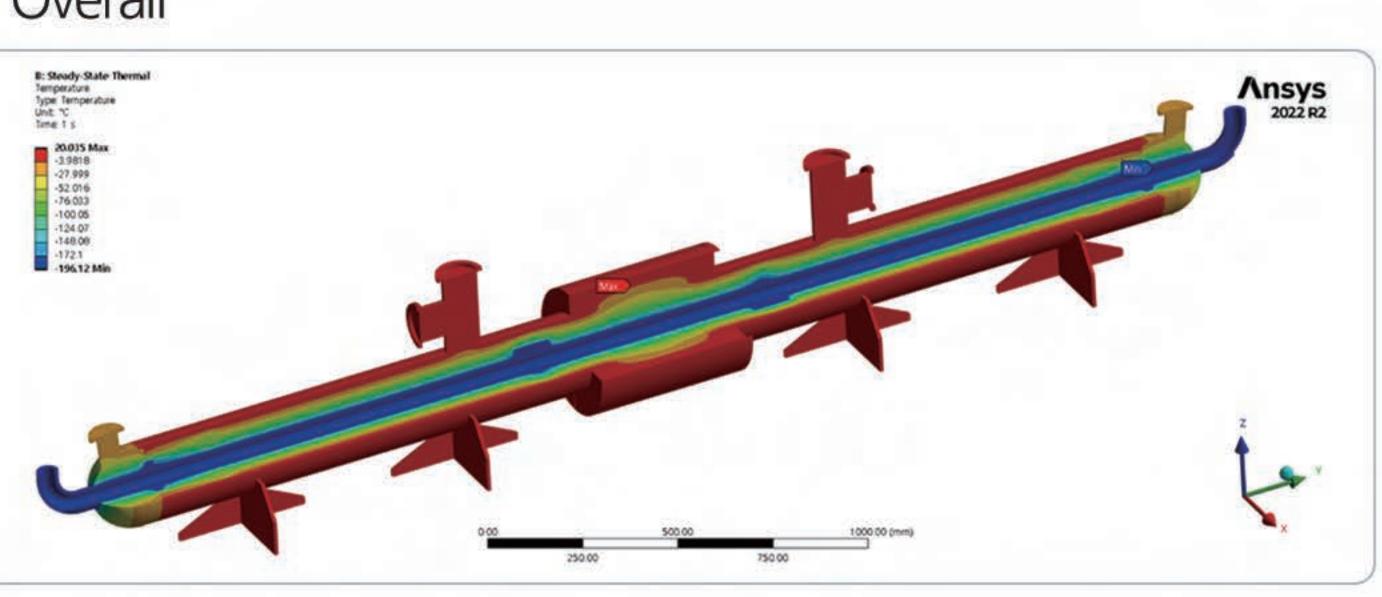
Vacuum Insulated Pipe were modeled using three-dimensional solid elements by Thermal-Structure Coupled Analysis. (Thermal Analysis: SOLID87, SOLID90 / Structural Analysis: SOLID186, SOLID187) and using COMBIN14 for Internal Flexible Support.

Temperature Distribution Analysis

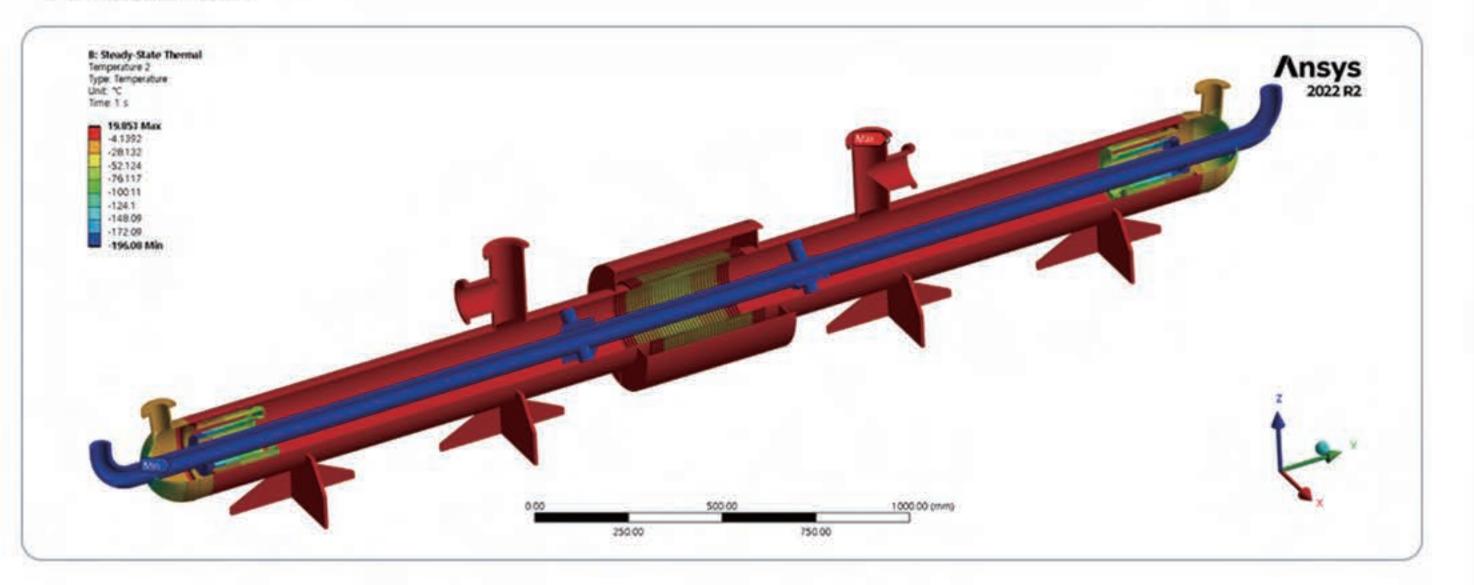
Thermal Analysis Results

| Location | | | 온도 [°C] | | Remarks |
|------------|---------------------------|------------------|---------|----------|---------------------|
| Overall | | | Max. | 20.035 | |
| | | | Min. | -196.12 | |
| | Overall | | Max. | 19.853 | Vacuum Port |
| | | | Min. | -196.08 | Inner Pipe |
| | Flexible Support | Support Ring & | Max. | -187.61 | |
| Campatons | | Spring Housing | Min. | -195.98 | |
| Structure | | Spring Pin | Max. | 17.558 | |
| | | (MC Nylon) | Min. | -191.46 | |
| | Inner Pipe End Support | | Max. | -0.93214 | |
| | | | Min. | -194.49 | |
| | Overall | | Max. | 20.035 | Air (Bellows Cover) |
| | | | Min. | -196.12 | Inner Pipe |
| | Vacuum (Perlite Power) | Overall | Max. | 19.854 | |
| Insulation | | | Min. | -196.12 | |
| insulation | | Bellows Inside | Max. | 18.774 | |
| | | | Min. | -196.02 | |
| | A:u | (Dallaria Carres | Max. | 20.035 | |
| | Air (Bellows –Cover) | | Min. | -31.654 | |

Overall



Structure



The Temperature Distribution of Vacuum Insulated Pipe

- The temperature distribution of Vacuum Insulated Pipe is shown in the table above.
- Heat transfer is conducted from the inner pipe to the spring housing to the stainless steel and MC nylon is from the housing to the outer pipe and has a very large temperature difference in Flexible Support, which has a low heat transfer rate and a short length of material in contact with the outer pipe.
- Even in the =-shaped bent end support, heat conduction is transmitted to the outer pipe. However, as the length of conduction increases, the temperature gradually changes and the part in contact with the external piping rises to -1°C.
- Iln Bellows, the temperature drains out to the outer pipe due to the thinness, but it is adjusted by Bellows Cover.

Structural Analysis

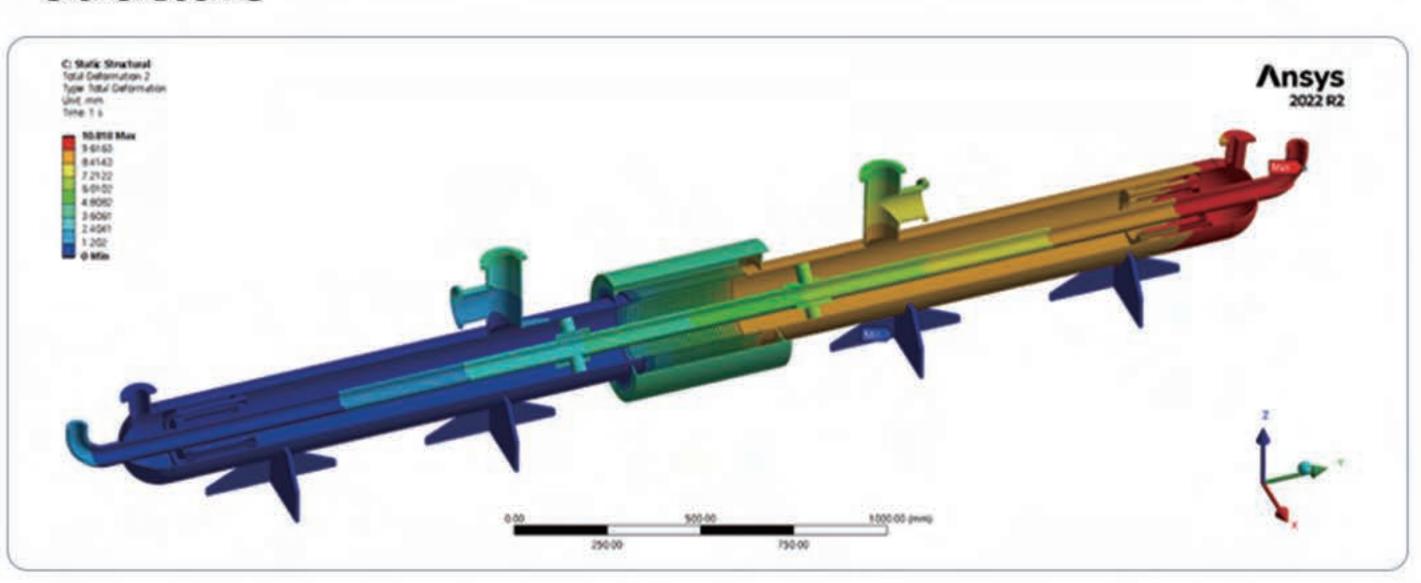
Structural Analysis Input Value

| Location | | 분류 | Input Value | | | |
|------------|---|----------------------------|--------------------------|-----------|-------------------|--|
| Overall | | 열하중 (Thermal) | Thermal Analysis Results | | | |
| Outor Dina | Outside | 압력 (Pressure) | 1 atm | 101.33 | N/mm ² | |
| Outer Pipe | Inside | 압력 (Pressure) | 5*10 ⁻⁴ Torr | 6.67*10-5 | N/mm ² | |
| | Outside | 압력 (Pressure) | 5*10 ⁻⁴ Torr | 6.67*10-5 | N/mm ² | |
| loner Dine | Model Inside 정수압 (Hydrostatic Pressure) 압력 (Pressure) | 밀도 (Fluid Density) | 810 | kg/m³ | | |
| Inner Pipe | | 성우합 (Hydrostatic Pressure) | 양정 (Free Surface) | 250 | mm | |
| | | 압력 (Pressure) | 1 atm | 101.33 | N/mm ² | |

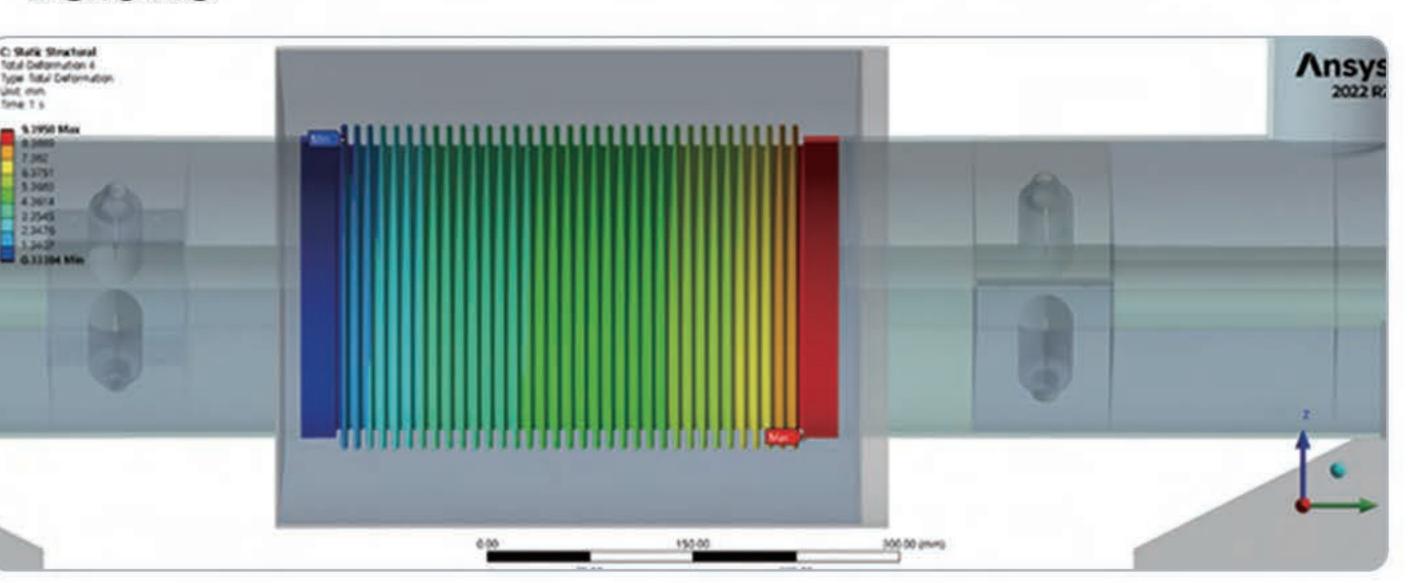
Deformation

| Item | Deformation [mm] | | Remarks | |
|-----------|------------------|---------|---------|--|
| Overall | | 10.818 | | |
| Structure | | 10.818 | | |
| D. II. | Max | 9.3958 | | |
| Bellows | Min | 0.33384 | | |

Structure



Bellows

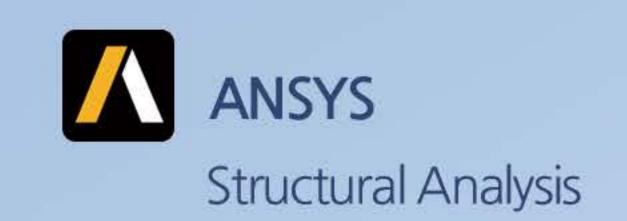


The deformation of the Vacuum Insulated Pipes resulted in deformation of approximately 10.818 mm due to heat shrinkage due to the temperature of LN2. The deformation in Bellows is 9.40mm, which is estimated to have absorbed most of the deformation caused by heat shrinkage from Bellows.

Work Performance Records for the last 3-years

| No. | Project Name | Company / Contractor | Duration | Remarks |
|-----|---|----------------------|-----------|----------|
| 14 | ITER - VS - Coil in Situ Winding Work - Staging & Prototype Design | IO / Yujin MS | 2022~2023 | On-going |
| 13 | Vacuum Insulated Pipe Design & Analysis | DuckCheun | 2022~2023 | On-going |
| 12 | Artificial Structure for Display | Government / GSI | 2023 | On-going |
| 11 | HD-10,000 F/C Mooring Design & Analysis | SK Ocean Plant | 2023 | On-going |
| 10 | Consulting of Method Statement for FOWT | SK Ecoplant | 2022 | Finish |
| 9 | Design of Special Lifter for Ship's Propulsion | Zvezda / DH Ent | 2021~2023 | Finish |
| 8 | Barossa FPSO - Structural Analysis | BWO / FG Ind. | 2021~2022 | Finish |
| 7 | Mumbai Trans Harbour Link Project - Marine Work & Installation Analysis | Daewoo TATA / DWST | 2021~2023 | Finish |
| 6 | Cable Protection System(CPS) Design Analysis | DWNT / Panduite | 2022 | Finish |
| 5 | ITER - Bracing Tools Manufacturing Design | IO / Yujin MS | 2022 | Finish |
| 4 | Lifting Work Procedure for Floating Crane | Kumyong | 2022 | Finish |
| 3 | Vibration Analysis for SCR | WK Industry | 2021 | Finish |
| 2 | Power System Design of Air Boat | Government / KUMHA | 2021~2022 | Finish |
| 1 | Development of Mine Laying System Design | Government / KUMHA | 2020~2022 | Finish |

Software & Tools







Orca3D Orca3D Marine Design for Rhinoceros



Dynamic Analysis Software for Offshore Marine Systems



Structure Analysis Computer System for Offshore Plant



PATRAN & FEA2007

Hull and General Structural Analysis Program



Geometric Modeling





Multi-Operational Structural Engineering Simulator, Motion & Stability Analysis





NASTRAN Analysis Solver





3D Drawing



Ballasting Calculation, Towing Calculation, Lug Calculation, Welding Calculation and Etc.



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