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Lightweight & CO2 reduction Solutions

High Tensile Strength Plates for High-Pressure Equipment in Sour Service Environment

By: Sarath Kumar [1] & Abishek Sundar [1]
[1] Precision Equipments (Chennai) Private Limited, Chennai, India.

INTRODUCTION

Excessive weight of Equipment is challenging in many forms like handling, installation and heavy foundation structure design, which may require specialized equipment and expertise. It adds to the overall cost of the projects and huge utilisation of Engineering strength.

Also, our fight against the climate change with key of CO2 reduction by transition to renewable energy is very limited to 55% globally and to achieve the net-zero emission by 2050, steel industry is one of the most important sectors. The excessive usage of steel is directly increase the production of steel as well as CO2.

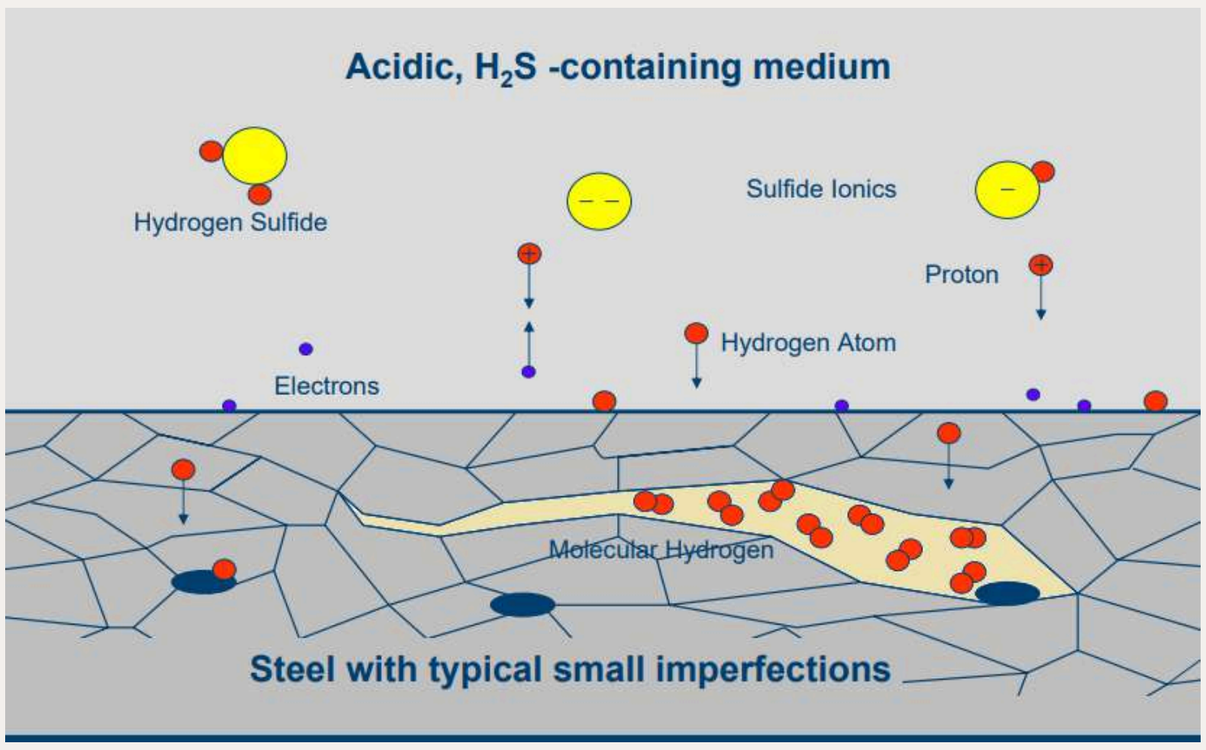
To mitigate these issues, Engineers and Designers must carefully consider the weight of high pressure equipment (specially vessels & exchangers) during the design phase and optimize them. Selection and utilisation of advanced materials to reduce weight without compromising performance is a key challenges to every Engineers and Designers.

In early days, Carbon steel (say SA 516 Gr. 60/65/70) material is selected for wide range of equipment, which resulted in excessive equipment weight and increase in subsequent foundation structural weight. Specially, offshore and FPSO is more concern on weight reduction by reducing the plate thickness of high pressure equipment.

Because of this necessity the steel industries came with the solution of High tensile strength quenched & tempered MnMo(Ni) alloy steels and the same is accredited by ASME standard as SA 533.
SA 533 is available in 5 different grades designated as A, B, C, D & E based on Nickel present in the plate material chemical composition & further classified into three different class based on its tensile strength. SA 533 Gr.B Cl.2 is a manganese, molybdenum, and nickel low-alloy steel plate with high strength used in pressure equipment.

HIGH STRENGTH PLATES FOR H2S ENVIRONMENT

However, the development of these high strength low alloy steels is not serving the purpose when the Equipment in wet H2S service ("sour service") due to challenging in weldability which satisfied with NACE MR 0175.



Equipment in sour service, which means they are exposed to environments containing hydrogen sulfide (H2S), face several specific challenges and risks due to the corrosive nature of H2S. The main issues that affect these pressure vessels are Sulfide Stress Cracking (SSC), Hydrogen-Induced Cracking (HIC), Stress Corrosion Cracking (SCC), Corrosion.

Materials resistant to H2S-induced corrosion and cracking are used to protect Equipment in sour service. For high pressure equipment, the selection of sour service carbon steel (say SA 516 Gr.60) or corrosion resistant alloy is not the cost effective and again leads to increase in excessive weight of equipment.

To address this issue, SA 533 Gr.E Cl.2 plates alternatively utilized. It is a high strength steel with lean chemistry delivered in quenched and tempered condition, that combines high tensile properties with good Charpy-V notch toughness at low testing temperatures and exhibits resistance to hydrogen-induced cracking (HIC) as good as the one achieved with carbon manganese steels.

The mechanical characteristic comparison of SA 533 Gr.E Cl.2 vs SA 516 is shown in Table-1.

	SA 533 Gr E			SA 516			
Parameters	**Class 1 ksi [MPa]**	**Class 2 ksi [MPa]**	**Class 3 ksi [MPa]**	**55 {380} ksi [MPa]**	**60 {415} ksi [MPa]**	**65 {450} ksi [MPa]**	**70 {485} ksi [MPa]**
Tensile Strength	**80 - 100 [550 - 690]**	**90 - 115 [620 - 795]**	**100 - 125 [690 - 860]**	55 - 75 [380 - 515]	60 - 80 [415 - 550]	65 - 85 [450 - 585]	70 - 90 [485 - 620]
Yield Strength, min	**50 [345]**	**70 [485]**	**83 [570]**	30 [205]	32 [220]	35 [240]	38 [260]
Elongation in 2in. [50mm] , min , %A	**18**	**16**	**16**	27	25	23	21

Table - 1 : mechanical characteristic comparison of SA 533 Gr.E Cl.2 vs SA 516

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In Table-2 Compared the ASME requirement on chemistry with one of the commercially available SA 533 Gr.E Cl.2 plate material, which has significant metallurgical adjustments to enhance the resistance towards the sour environment. Some of the chemistry adjustments with advantage listed below are.

- Low Carbon content to ensure good weldability.
- Balanced alloying of Mo and Cr to guarantee strength properties.
- Ni addition for hardenability and impact toughness. Ni content is below 1% as per ISO 15156-2.
- No microalloying (V, Ti, etc.) to ease HAZ softening.
- Very low levels of tramp elements (S, P); S and P contents are much lower than what is specified in ASTM A533 because these elements are detrimental to resistance to hydrogen-induced cracking (HIC) and impact toughness properties (say >100J @ -50 Deg C).

		C	Mn	P	S	Si	Mo	Ni	Cr	Ti	V
ASME SA-533 type E	Heat	≤0.20	1.15-1.70	≤0.020	≤0.015	0.15-0.40	0.25-0.60	0.65-1.00	≤0.60	≤0.030	≤0.030
	Product	≤0.20	1.04-1.84	≤0.020	≤0.015	0.13-0.45	0.21-0.64	0.57-1.03	≤0.64	≤0.040	≤0.040
Test plate	Heat no.22407	0.10	1.26	0.006	0.001	0.16	0.50	0.88	0.52	0.002	0.005
	Product	0.11	1.25	0.006	0.002	0.15	0.49	0.91	0.53	0.002	0.005

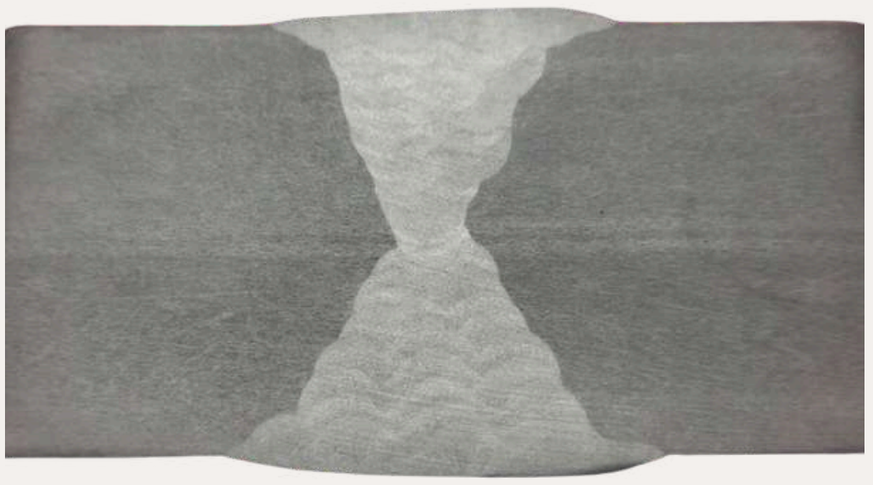
Table - 2 : Chemical composition of the tested material in mass wt.% (Balance Fe)

WELDING OF SA 533 GR. E CL.2

Welding with conformance to NACE MR 0175 is more importance factor in the fabrication of heavy equipment in sour environment. Precision Equipments has well established welding qualification for SA 533 Gr.E Cl. 2 with the following specifications in controlled manner.

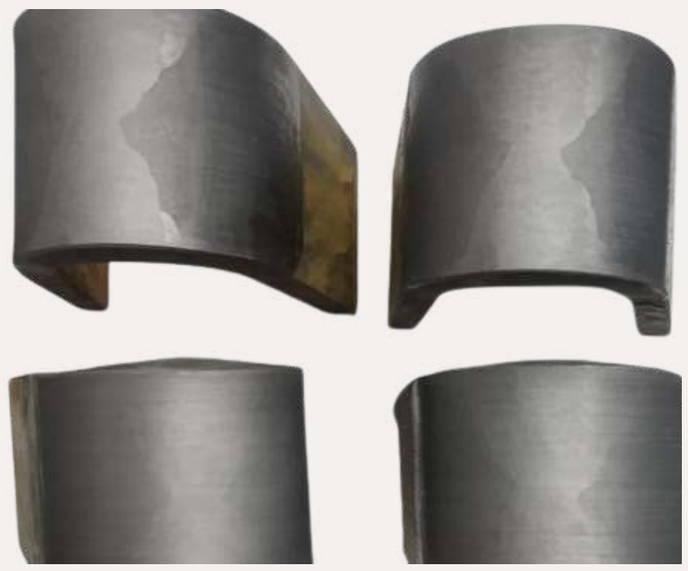
- Welding Process: SMAW + SAW
- Base Material Specification: SA 533 Gr.E Cl 2
- SMAW Electrode Specification: E 9018-G
- SAW Wire Specification: EF3
- SAW Flux Classification: AUTOMELT B20 PLUS

Following welding, Post Weld Heat Treatment (Simulation Heat treatment) were done on weld coupons with 620°C @ 2 Hours (Min. Cycle) & 6 Hours (Max. Cycle).



SA 533 Gr. E Cl.2 weld coupon undergone the following test and results are meet NACE & service requirement.

- Tensile Test
- Side Bend Test
- Macro Examination
- Hardness Examination
- Charpy “V” Notch Impact Testing @ -46° C



THICKNESS COMPARISON : SA 516 GR 60 VS SA 533 GR.E CL.2

SA 516 Gr.60 (HIC-resistant quality) is the present plate material used for the fabrication of high pressure equipment in severe sour service. Due to the high pressure and heavy thickness, it may be of interest to consider the use of higher strength materials such as SA 533 Gr.E Cl.2 for wall thickness (weight) reduction.

Allowable stresses for materials SA 516 Gr.60 and SA 533 Gr.E Cl.2 for vessels designed according ASME Section VIII, Division 2 Class 2 can be found in Tables 5A of ASME Section II, Part D. A comparison of allowable stresses for both materials is shown on Figure - 1.

PV Elite design was performed for the Design pressure of 160 kg/cm2 with varying the design temperature and comparison made for SA 533 Gr.E Cl.2 vs SA 516 Gr.60 and thickness results as per ASME Sec VIII Div.2 Class 2 are shown in Table 3.

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From the table.3, it is well demonstrated that the higher allowable stresses than carbon steel grades, SA 533 Gr.E Cl.2 provides a significant reduction of vessel wall thickness, and therefore weight reduction. Also observed that we can achieve upto about 50% reduction in wall thickness depending on vessel and design parameters.

Design Parameters:

Design Pressure: 160 kg/cm2

Design Temperature: 100/150/200/250/300/350 °C

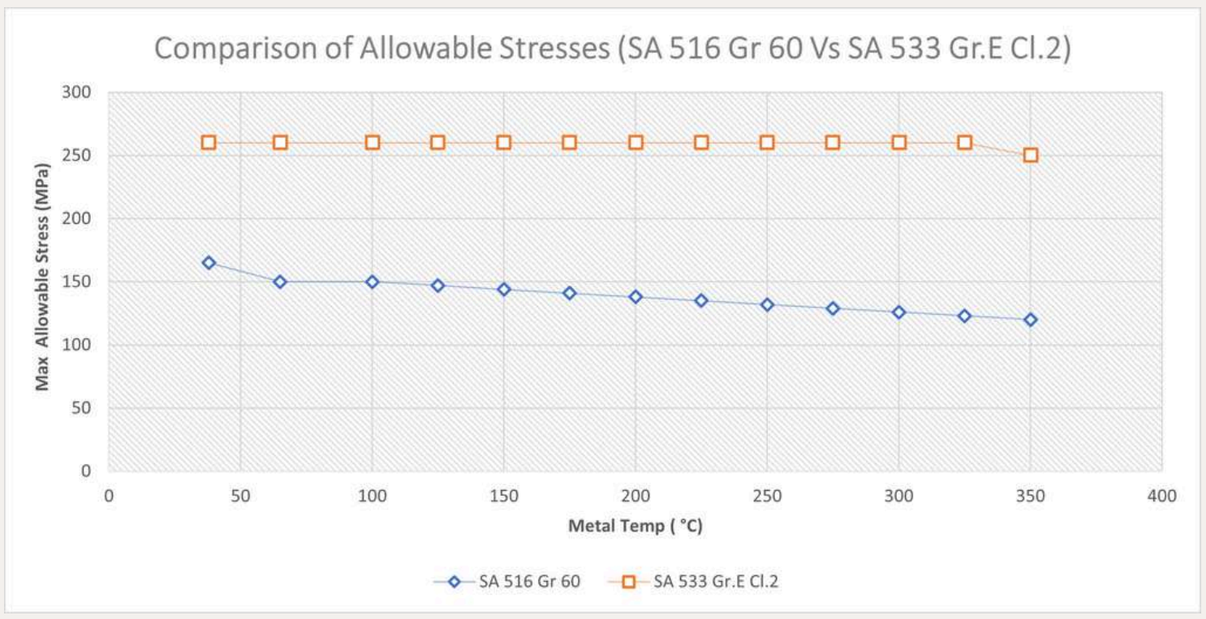

Figure - 1 : Comparison of allowable stresses for SA 516 Gr 60 & SA 533 Gr.E Cl.2

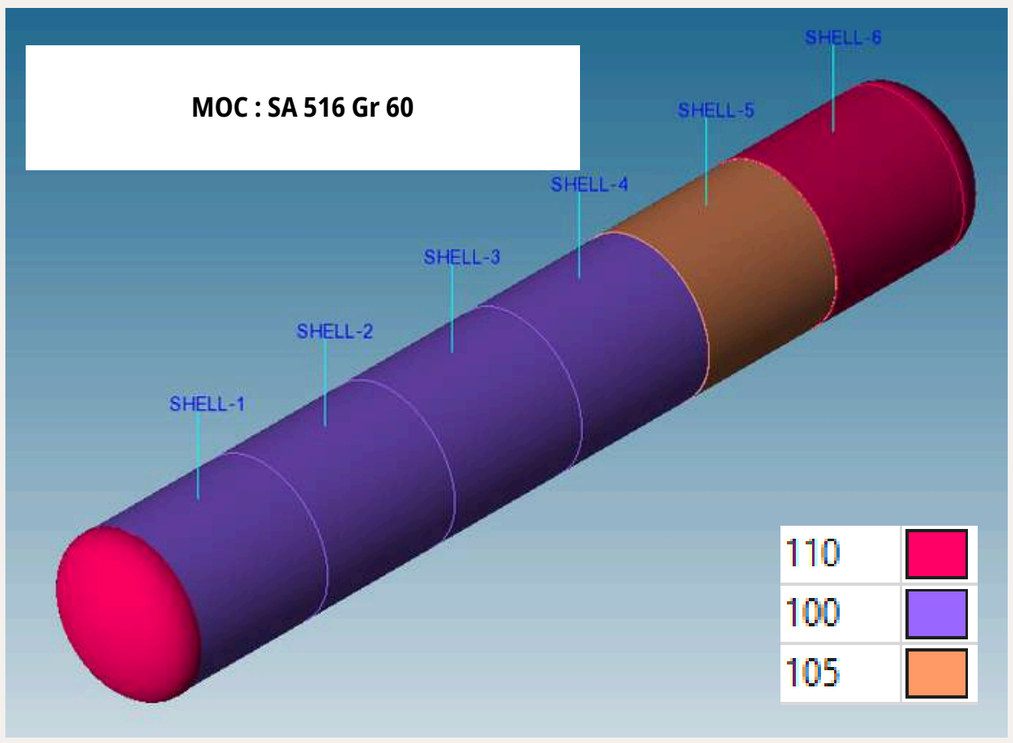

Figure (b) : Thickness Profile (in mm) for SA 516 Gr 60

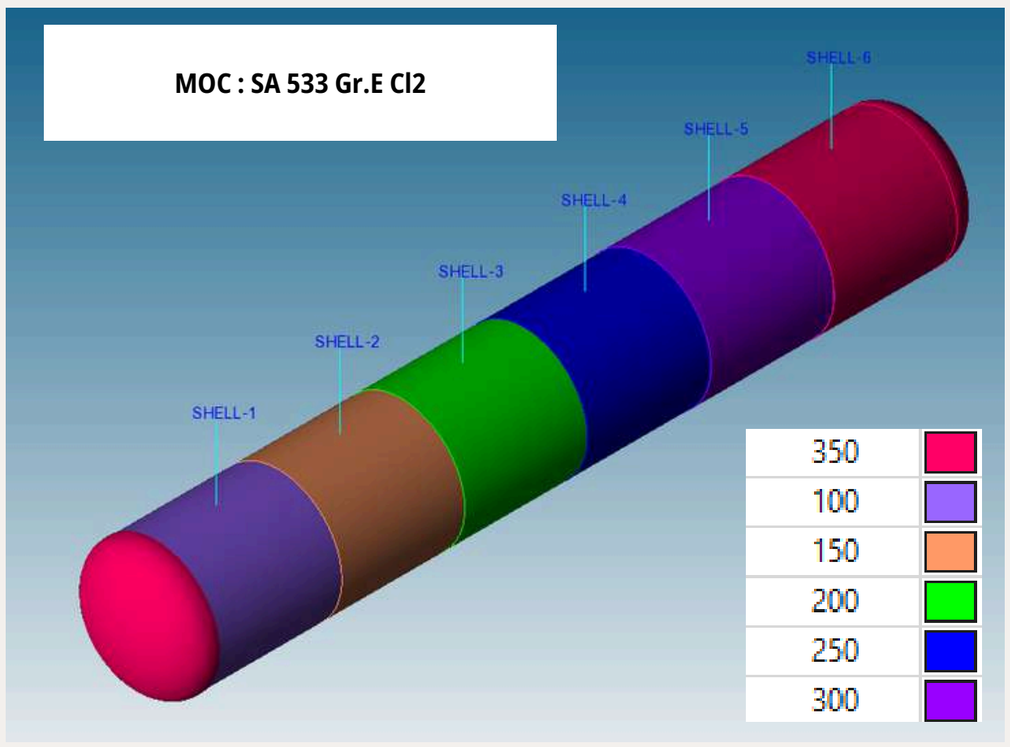

Figure (c) : Temperature Profile (in °C) for SA 533 Gr.E Cl2

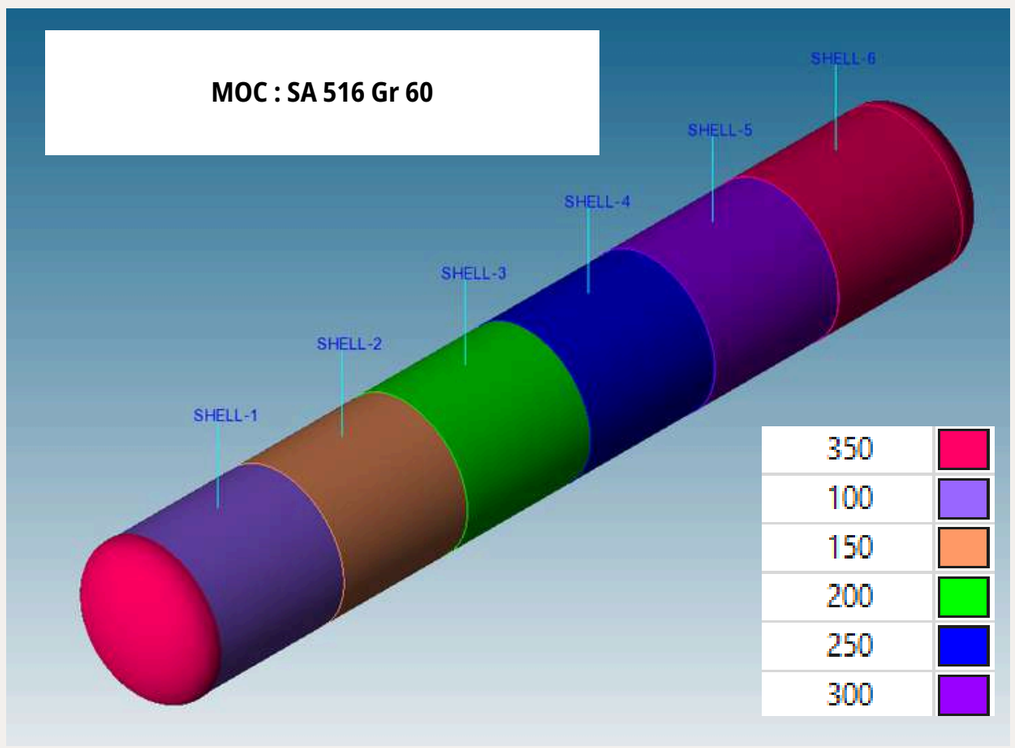

Figure (a) : Temperature Profile (in °C) for SA 516 Gr 60

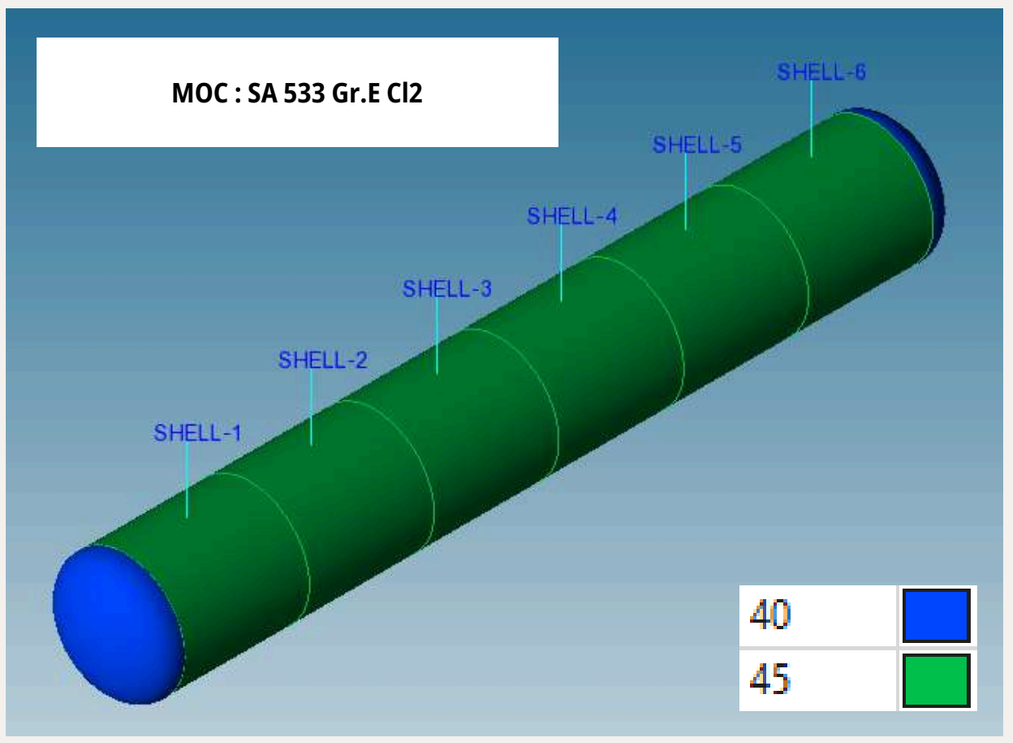

Figure (d) : Thickness Profile (in mm) for SA 533 Gr.E Cl2

Temperature (°C)	100	150	200	250	300	350
SA 516 Gr 60	100 (SHELL)	100 (SHELL)	100 (SHELL)	100 (SHELL)	105 (SHELL)	110 (SHELL)
SA 533 Gr E Cl.2	45 (SHELL)	45 (SHELL)	45 (SHELL)	45 (SHELL)	45 (SHELL)	45 (SHELL)

Table - 3 : Thickness Comparison of SA 516 Gr 60 & SA 533 Gr.E Cl.2

BENEFITS

It is concluded that the weight of High pressure Equipment in sour service might be optimized significantly by high strength SA 533 Gr.E Cl.2 with specific welding parameters established by the experienced solution providing manufacturer like Precision Equipments.