Case Study

AMEC

Buckling Analysis of a Condensate Storage Tank

Company Profile

AMEC is one of the world's leading engineering, project management and consultancy companies providing services to the world's oil and gas, minerals and metals, clean energy, water and environmental sectors in around 40 countries around the globe.

AMEC's services covers design review for all aspects of storage tank design, inspection, refurbishment and construction. Offering a wealth of experience for EPC (Engineering, Procurement, and Construction) projects, AMEC can offer tailored solutions for all types of storage tanks including the refinery sector, oil storage depots, power stations, nuclear power, water storage and chemical processing plants.

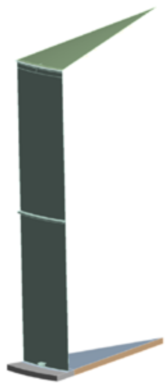
Background

Natural gas condensate is a low-density mixture of hydrocarbon liquids that are present as gaseous components in raw natural gas produced from natural gas fields. The condensate comes out of the raw gas if the temperature is reduced to below the hydrocarbon dew point temperature of raw gas. A condensate storage tank comprises a tank section with a condensate outlet at the lower end and nitrogen blanket system connected to the upper end of the tank section.

AMEC requested a Finite Element Analysis (FEA) to be carried out on a newly constructed tank to establish the stress distribution for normal operational conditions, and to evaluate the critical load to cause buckling. Most importantly, the analysis should determine the impact of an internal overpressure in the tank, and whether failure to the roof/curb joint occurred before failure at the wall/floor joint. Expectation from AMEC was to confirm that any failure of this nature would result in condensate remaining within the storage tank, and not result in a spillage.

The conclusion of the analysis would provide AMEC with guidance as to whether further works to the frangibility of the roof joint needed to take place. This case study describes the analysis procedure and the conclusions that were reached.

Analysis



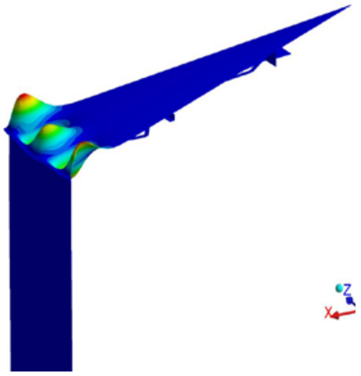
IDAC carried out structural FE analyses, using ANSYS, of the condensate storage tank design incorporating the frangible roof joints. The objective of the analysis was to evaluate whether, or not, the roof/curb joint would fail before the floor/wall joint. The analysis conditions were provided by AMEC. A 1/16th symmetry sector of the storage tank was modelled as shown in the graphic to the right. Taking advantage of cyclic symmetry allowed a more detailed model to be developed and hence a more accurate solution to be calculated. A 1/16th segment was considered to be the minimum size that could be modelled to allow for challenging geometry of the storage tank (10m diameter span of the tank and 6mm thickness of the roof and wall), whilst maintaining reasonable computational times. Half of the stiffener beam was modelled on one plane of symmetry of the 1/16th sector, whilst the other plane of symmetry was modelled as being mid-span of the stiffener beams. The model, (including the welds and stiffener beams) was meshed entirely with solid elements; this allowed for stresses and strains to be evaluated through the welds and the thickness of the roof and floor.

The analysis was carried out in two phases:

- Linear buckling analysis to evaluate the buckling modes and critical buckling pressure
- Non-linear buckling analysis to obtain more accurate results

IDAC, Airport House, Purley Way, Croydon, Surrey, CR0 0XZ, England
Tel: +44 (0)844 212 5900 **Fax:** +44 (0)844 212 5910
Email: info@idac.co.uk **Homepage:** www.idac.co.uk

Phase 1: Linear Buckling Analysis (Eigen Value Approach)



A 1/16th segment of a circular tank was created and analysed with symmetry boundary conditions, hydrostatic pressure, gravity and an initial gas pressure. Using this pre-stressed model, a linear buckling analysis was carried out to obtain the lowest buckling mode shape either at the top or bottom corners of the tank. The load multiplier value was noted for the buckling mode shape of interest. The procedure above was then repeated by applying a new gas pressure each time (calculated from the equation below) until the load multiplier became approximately 1. The final pressure value calculated was taken to be the critical buckling pressure.

New Gas Pressure = Previously Applied Gas Pressure x Load Multiplier

The first buckling mode for the tank body can be seen in the graphic to the left.

Phase 2: Non-Linear Buckling Analysis

A non-linear buckling analysis was carried out as it would provide more accurate results than the Eigen Value approach described above in Phase 1. The model was analysed with geometric and material non-linearities, using the critical buckling pressure calculated above and boundary conditions as described above. The analysis was carried out to confirm whether the tank could withstand the critical buckling pressure safely and also to evaluate the pressure at which the material reached 10% plastic strain. A small geometric imperfection was required to be present at the start of the analysis, to trigger the non-linear buckling analysis; this was done by using the buckled mode shape calculated from the linear buckling analysis.

Conclusions

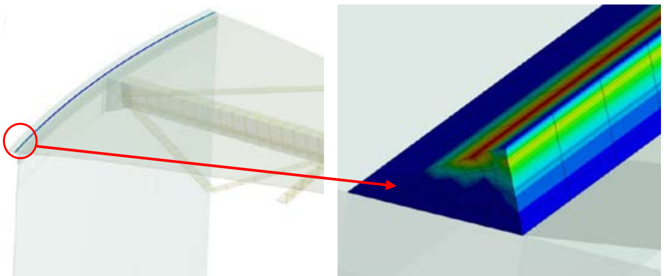
From the non-linear analysis a more accurate critical buckling pressure was calculated, as well as a safe pressure where the plastic strain remained below 10%. The analysis confirmed that the tank could withstand the critical buckling pressure safely.

The pressure at which 10% strain was reported was also calculated and was found to be 17% higher than the critical pressure load.

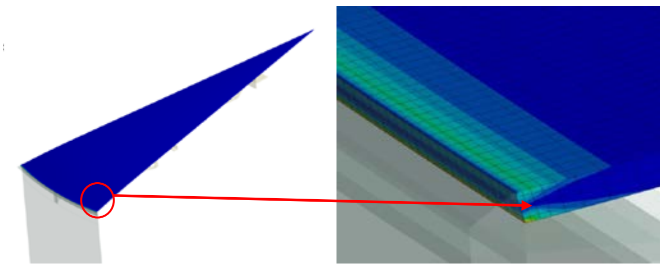
It was found that the top and bottom welds were the critical welds in the tank. The analysis also showed that the first region to experience plastic strain greater than 10% was in the roof weld. From the results it was concluded that the roof would fail first at the side which was welded to the curb bar, and that the failure would then proceed through the thickness of the weld. This result satisfied the customer as the condensate storage tank was required to fail first at the roof/curb joint to allow gases to escape rather than any of the condensate.

The graphics above right show the equivalent plastic strain in the top weld and roof.

Top Weld



Roof



Design Benefit

IDAC were able to evaluate the internal pressure and location at which the local buckling occurred. AMEC having worked closely with IDAC, were able to present the recommendations to their client with confidence having gained an insight into the behaviour of the various components of the Condensate tank. Alan Hopgood of AMEC said "The report was well received by both AMEC and our client. The FEA analysis provided assurance to both the client and AMEC that any unexpected overpressure within the tank would not result in the loss of condensate inventory. Based on the report findings, a decision was reached within the project that no further construction work was required on the tank roof joints to improve the roof frangibility."

IDAC, Airport House, Purley Way, Croydon, Surrey, CR0 0XZ, England
Tel: +44 (0)844 212 5900 **Fax:** +44 (0)844 212 5910
Email: info@idac.co.uk **Homepage:** www.idac.co.uk