The current economic challenges that are present in the petroleum industry have driven companies to find ways of leveraging technology to improve efficiency, productivity and profitability. Meeting the software demands of the upstream, midstream and downstream sectors of the oil, gas and petrochemical (OGP) industries is a daunting task. Each of these sectors have unique needs and, as a result, software requirements are diverse, depending on the sector that is examined.

Because the topic of software applications in the petroleum industry is so vast, this article will focus on engineering software tools that are utilised in the downstream sector by engineering, procurement and construction (EPC) firms to improve design efficiency in projects, subcontractors that support EPC firms with ancillary design services, and contractors that construct them.

Like many industries that have applied computers and software to improve design efficiency, the EPC design process had its roots in a labour-intensive 2D computer aided design (CAD) manual drafting workflow, which generated project representations, general arrangement (GA).

Michael Smith and Jana Miller, Hexagon PPM, USA, share the benefits of using 3D modelling and analysis software in downstream plant applications.

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drawings, piping and instrumentation diagram (P&ID) schematics and isometric piping drawings. Over time, 2D CAD software improved and evolved into 3D modelling solutions that can create comprehensive 3D plant designs.

Intelligent 3D models using advanced software tools offer capabilities beyond modelling. They deliver value through automation to all project stakeholders in support of purchasing, scheduling, construction co-ordination, fabrication, operations and maintenance, etc.

Hexagon PPM (previously known as Intergraph) offers software tools that can be used to design and construct tankers, refineries and pipeline projects. Subcontractors can also use the software to share data in a collaborative project execution.

One such subcontractor is Rishabh Engineering Services, a division of Rishabh Software, that offers support solutions to EPC companies, including engineering and stress analysis, design and detailing, 3D modelling, as-built documentation and design validity checks, along with model and drawing conversion.

**Refinery heaters project**

Rishabh Engineering was chosen to perform stress analysis for eight heaters of various units in a refinery in Billings, Montana, US, by Optimised Process Furnace. Its scope was to undertake the analysis work on all stress-critical lines that were connected to the following:
- Vacuum heater.
- Large crude heater.
- Splitter boiler.
- Propane regeneration unit.
- Ethane regeneration heater.
- Fluid catalytic cracking unit (FCCU) superheater.

The client was a US multinational energy company, headquartered in Texas, working predominantly in the petroleum refining and chemicals businesses. It currently owns and operates five domestic oil refineries and related assets.

The company successfully delivered its task and confirmed that the new coil designs were adequate for the metallurgy change in the convection section, from 317L to 347L, as well as the pipe diameter change in the lower radiant section. The projects involved a total of 2800 man-hours.

A variety of deliverables were produced, including:
- Piping stress reports.
- Assumptions, consideration and suggestion reports.
- Simplified report for support design (induced forces, moments and displacements at support locations in a simplified manner).
- Isometric support mark-up.

**Vacuum heater and bowing effect**

Because of the location and burner/heat exposure, there is a temperature difference between two sides of pipe. This causes a pipe deflection called a ‘bowing effect’. The client requested that the bowing effect was only considered for radiant zone coils, not for the convection zone. The effect of thermal bowing (6 in. displacement in lateral direction) only needed to be considered for radiant coils to simulate the maximum expected bowing height for a temperature difference of 300°F. Rishabh Engineering performed a bowing effect analysis for the entire coil assembly, including convection coils, crossover pipeline and radiant coils.

The company also performed a flexibility analysis on the process coil from inlet connections to outlet connections (i.e., radiant and convection process piping) and boiler feed water coil (upper convection), from inlet manifold to outlet manifold. It provided support for the horizontal radiant single-fired tubes in coking service, which include an allowance for movement designed to accommodate or restrain lateral movement due to bowing associated with the 300°F temperature differential from the tube’s hot face to its cold face. Rishabh Engineering also performed an analysis to evaluate the 5 in. lower radiant tube for the effects of bowing associated with the temperature differential.
Horizontal heater
The client also needed to change the tube metallurgy for operational safety of the system. It asked Rishabh Engineering to undertake another piping stress analysis to confirm whether the coil design was adequate. The metallurgy change in the convection section ranged from 317L to 347L and the pipe diameter changed in the lower radiant section. The client wanted to show the installation of a piping anchor at the radiant outlet tubes to force the thermal expansion into the heater and take the piping loads off of the transfer piping outside.

Project challenges and complexities

Route modification in crossover piping
In this project, Rishabh Engineering found that the crossover pipe was compact and congested. Initially, the team recommended a modified route for the crossover pipe. However, the client insisted that the company stick to the existing routing. The pipe was reanalysed by changing the dimensions of a few elbows from short radius to long radius, which made the area and pipe more flexible.

Documentation
The coils had multiple passes, with several coil layers stacked together. Defining the node number for the coils was difficult due to a large number of nodes being congested around the coil bends. For this, the nodes were grouped together and put under criteria, defined by support types.

Project-level
Rishabh Engineering was given tight schedules and faced resource allocation challenges. The EPC project would need to scale up its number of pipe stress analysis software licenses, depending on project demand. It also needed to adhere to international standards strictly and communicate clearly and seamlessly with its client.

Overcoming challenges
Revising the piping layout near the pump nozzles was troublesome, which led to further efforts and challenges. However, this was eventually addressed by providing spring hangers at required locations and changing pipe routing wherever possible.

The systems comprised piping configuration with multiple feed and return locations that needed defining at multiple temperatures to account for hot and cold conditions. Rishabh Engineering used Hexagon PPM’s CAESAR II pipe stress analysis software, which facilitated simple and clear analysis by enabling nine temperature cases.

The systems were complex, with the piping configuration consisting of almost 50 supports, thus making it a tedious task to check for lift-off supports. The alternative sustained stress (Alt-SUS) case in the pipe stress analysis software helped reduce this burden.

The team had been given non-editable GA drawings as input, which provided a top view of the heater. This meant that only the cross section view of the coils was observable. Since the client had not provided native files for the heaters, Rishabh Engineering modelled the stress critical systems in CADWorx plant design software before importing the files into CAESAR II. As a result, an accurate model of the heater coils was obtained and quick amendments to the model could be made if the line failed.

The software’s input graphics module makes the process of developing analysis models and clearly indicating areas of concern more simple.

The client’s expectations and the EPC’s limited resources were fulfilled effectively by reducing the modelling, stress analysis and documentation time. In turn, this reduced the actual man hours by approximately 7%, from an estimated 3000 man-hours to approximately 2800 man-hours.

Using this analysis software avoided delaying the scaling up of licenses and ensured that stress reports were comprehensive. The subcontractor did not have to use separate tools for nozzle analysis and isometric generation, which avoided the compatibility issues that often arise from the use of different software.

Applications of software interoperability
So far, this article has focused on the benefits of using 3D modelling and analysis software in brownfield project applications. Many oil and gas operators are currently faced with budget cuts, often causing greenfield projects to be put on hold until the industry shows signs of a recovery. Economic conditions are improving, albeit slowly, meaning that these operators are having to keep existing plants operational for extended periods of time.
even though they may be at the end of their lifecycle as an asset. Software can assist operators in maintaining plants. Corrosion and ageing systems within an existing plant pose reliability concerns and possible safety issues. A regular risk-based inspection (RBI) plan is an acceptable best practice, through which various piping systems and equipment are evaluated. While any problematic conditions can be identified and documented, merely identifying these does not remedy them. Left unattended, these problems can (and often do) result in system failures, which can cause needless and costly operational downtime and/or potentially catastrophic consequences.

Proactively mitigating problems in the plant is the key to preventing disruption to production. The RBI process includes steps and procedures to track problems through specific milestones and concludes with reassessment of the original issue(s) once the steps have been taken to mitigate the problem.

A simple issue like a corroded valve can be remedied quickly by replacing it. More complex issues, such as corroded pipe lines or vessels, may require extensive remediation, depending on the nature of the problem and the impact to operations of the plant.

Software helps with complex remediation activities by capturing the as-built condition as a 3D model. Traditional manual field measurement techniques may be sufficient when problems are simple. As the issue grows in complexity, it may be more effective to utilise laser scanning, in combination with 3D software, to create an accurate representation of the existing condition.

Once the as-built 3D model is created, additional analysis software can be applied to analyse the fitness for service (FFS) of piping components, vessels, exchangers, tanks, steel structures, etc.

The key to this workflow is software interoperability. That is, software products can exchange 3D models and data seamlessly to effectively leverage the data in one software application as the basis for another. In the case study presented in this article, the as-built 3D models provide a basis for software to perform analysis of FFS conditions.

**Conclusion**

FFS defines the best practice and standards that govern the OGP industries for in-service equipment to determine its fitness for continued service. Rishabh Engineering’s FFS methodology is mainly based on API 579, BS 7910 and is governed by the essential engineering concepts and calculations, characterisation of flaw and fracture mechanics approach. The company uses a practical approach that helps management professionals assess the remaining life and integrity of components, and recommendations on alternative actions to run, repair or replace the equipment.