API650 Tank Design Automation System

Ryan Fish

Andrew Guzzomi
School of Mechanical and Chemical Engineering

Mike Raine
CEED Client: Complete Hydrocarbon Systems and Solutions

Abstract

Complete Hydrocarbon Systems and Solutions is a small engineering firm based in Perth Western Australia. They specialise in design and construction of storage systems for hydrocarbons. Designing a storage tank to comply with the standard API650 takes around 100 man-hours per year and generates around $30,000 in revenue annually. API650 tank design involves the completion of a set of calculations to ensure the tank will be structurally safe and be able to carry out its desired function for the required service life. The standardised nature of these calculations meant that there was potential for the calculations to be automated. This project aimed to create an automation system that completed all calculations required for API650 Tank Design, and provided all relevant output data to the client for review. All relevant calculations were written through the software program Mathcad and the automation system also ained to incorporate the generation of 2D and 3D computer aided design models through the program Solidworks, with these also being provided to the client.

1. Introduction

Designing a storage tank in today's engineering world is often a time consuming process filled with many calculations. The tank design must be safe, cost effective and be able to function over the entire desired service life. For an engineer to design such a tank they must work through an industry standard, painstakingly checking through each detail and completing calculations that ensure the tank will be able to function within its limitations. When the engineer also has to factor in the storage of a high value liquid such as a hydrocarbon, there are even more factors to consider. Corrosion, tank pressure, and other factors contribute to the design of the tank.

Complete Hydrocarbon Systems and Solutions (CHSS) is a small engineering firm based in Perth, Western Australia. They specialise in the transport and storage of hydrocarbons in all conditions, and have successfully completed many projects around Australia and abroad. CHSS and its principal engineer Mike Raine see a need for a specific program to be developed, automating the FEED process to make the design much more efficient. Currently at CHSS, API650 tank design generates around $30,000 revenue annually, and takes around 100 man hours to complete. The successful completion of the project will greatly benefit the company, reducing the man hours used, increasing the revenue generated and opening the company up to a whole new market of potential clients. This can be achieved through successful implementation of the project. The project's ultimate goal is to become an internet driven subscription service, where clients pay a small fee to use the software, and from the software get the required information to decide if constructing a tank in a desired location is feasible. If the client chooses to go ahead with this, there is potential for CHSS to pick up the tank construction contracts, which will generate revenue much greater than the current $30,000 per year that CHSS currently earns.

1.1 Tank Design History

Demand for hydrocarbons first started to grow in the early 1900's. With demand of any product there will always be people willing to supply and with this came the requirement for the design of storage tanks for hydrocarbons. This demand is shown in Figure 1 where it can be seen that the production of crude oil in the United States after 1900 steadily increased regardless of economic climate.

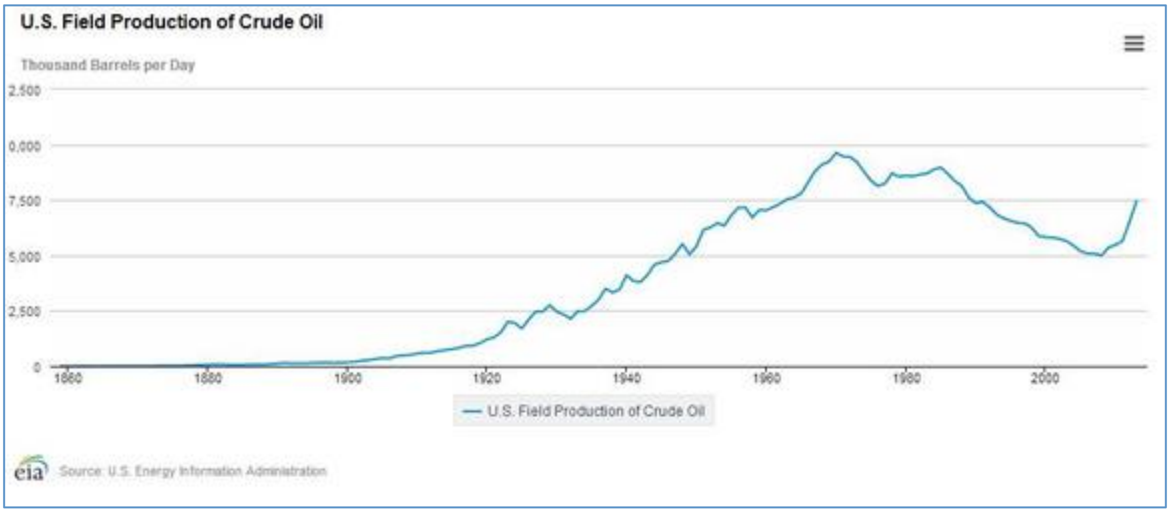

Figure 1: US Crude Oil Production (US Energy Information Administration, 2015)

Tank size and shape evolved as technology improved. Industry moved away from the use of wooden barrels and embraced the use of steel tanks for the storage of hydrocarbons. However it wasn't long until it was found that steel storage tanks had issues of their own that affected the successful storage of liquids. Steel is susceptible to corrosion and this became a major issue for engineers when designing their tanks, where up to 20% of the storage product can be lost due to corrosion (Maheri, 2013) The current method employed in industry to combat corrosion is the use of a corrosion allowance. The American Petroleum Institute defines a corrosion allowance as any additional thickness specified by the purchaser for corrosion during the tanks service life (API650, 2013).

External forces are another factor that engineers need to take into consideration when designing a storage tank. Depending on geographical location, some tanks could be prone to seismic forces, wind forces, or a combination of both. Forces due to wind vary depending on geographical location, tank shape, size, and tank anchorage. Uplift forces occur on both anchored and unanchored tanks, and while they may not cause the tank to buckle, they can damage tank connections that may result in a fire hazard (Hamdan, 2000).

Seismic forces can cause a tank to fail in either elephant foot buckling or diamond shape buckling. These buckling methods can be seen in Figure 2 and both forms of buckling are caused by a combination of compressive stresses and seismic loading. Low height to radius ratios are a main factor in elephant foot buckling (Hamdan, 2000) while diamond buckling can occur on both anchored and unanchored tanks. Studies have shown that unanchored tanks are generally more susceptible to buckling (Niwa & Clough, 1982).

Figure 2: Elephant Foot (L) and Diamond Shape Buckling on a Tank (R) (Malhotra, 2006)

Tank construction involves curved metal plates being welded or bolted together. The welding or bolting process is usually completed one strake at a time, where a strake can be defined as a complete horizontal layer of metal plates. Welding is preferred to bolting or riveting as it requires less material and manpower to complete. Less material means lighter strakes, and no bolt holes means a watertight seal (Kumar & Kumar, 2006).

1.2 API650

API650 Welded Tanks For Oil Storage is the standard used worldwide to design a storage tank that is required to store a hydrocarbon. The calculations can be split into two parts, shell design and roof design. Roof design is dependent on local standards, and as this project only focussed on API650 tank calculations, the roof design component is omitted. Section 5 in API650 covers shell design, and provided a complete set of calculations required to design a storage tank. Relevant sections of shell design include Shell Thickness, Wind Girders, Wind Load Stability and Seismic Design and these are discussed in greater detail below.

2. Process

The process involved in successful implementation of the automation system invovles the use of a number of software programs. The first program required for the automation system is Mathcad, which was specifically chosen by CHSS. Mathcad would hold and complete all the calculations required in API650 tank design, and the outputs of these calculations could then be used in a final outputs sheet to be handed to the client. The second software package that would be used would be Solidworks. Solidworks was chosen because of its superior 2D and 3D modelling capabilities.

Before automation could be created, all calculations had to be ordered and written out by hand. Completing hand calculations was also a great way to experience what it would have been like to undergo an API650 tank design process manually.Once all calculations were written out, they could be put into separate Mathcad sheets based on what type of calculation they were. The calculations and Mathcad sheets were ordered because some calculations depended on others. The overall Mathcad sheet order can be seen in Figure 3 which highlights dependencies between some sheets.

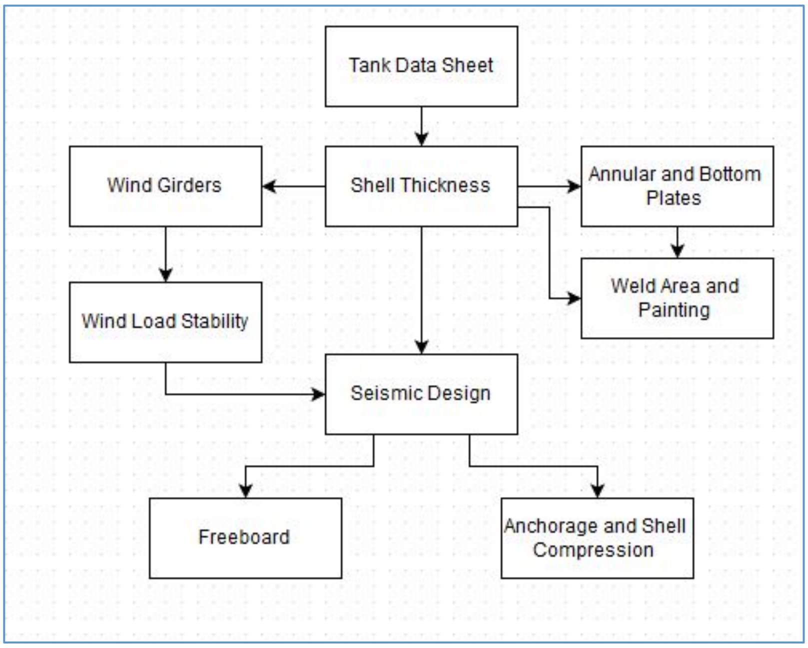

Figure 3: Mathcad sheet flow chart

Once all data could be obtained the original concept was to send the data through to Mathcad via a "Mathcad to Solidworks" add-in. However the add-in was not compatible for the current versions of Solidworks and Mathcad, and as such Microsoft excel was utilised as a link between the two. This also meant that the Visual Basic for Applications component of excel could be utilised to create the user interface. The use of Excel was also beneficial as it meant the final outputs document could be generated easily.

After finalising the calculations and software required to create the automation process, macros within excel were written and the final process layout shown in Figure 4, was determined.

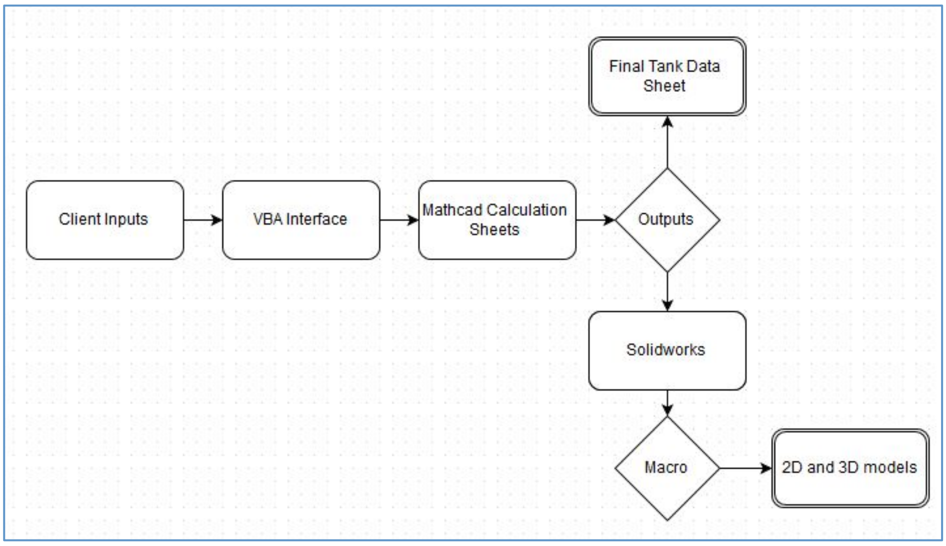

Figure 4: Final automation process layout

3. Results and Discussion

For the automation process to be deemed a success, it needed to be compared to a case study. A successful automation system would be able to produce all calculation data faster than the case study while still producing all the correct data. The case study that was selected was taken from a dissertation written by Siew Yeng for the University of Southern Queensland in 2009. This dissertation explored the design, construction and operation of a floating roof tank and included a set of calculations for his tank design. After disregarding the irrelevant data such as the roof calculation, comparison could be made between the calculations. Siew Yeng estimated that to complete all facets of the tank design calculation would have taken between 10 and 20 hours, which is a fair estimate considering the time taken to complete initial hand calculations was around the same time frame.

Taking all initial data and running the automation system showed some mixed results. Time taken to complete all calculations and send them to the final outputs sheet was only 5 minutes, which is a massive time reduction in comparison to Siew Yeng's 10 hours. While this time reduction means the project was a success, the fact that some small sections of the standard were omitted due to time constraints mean there is definitely potential for future work to be completed in this field.

4. Conclusions and Future Work

While the concept of an automation system for API650 is an excellent idea, its implementation was much more complex than originally thought. While the system provided a large reduction in time taken to complete calculations many output values differed to the case study completed by Siew Yeng. The exclusion of some sections of the standard due to automation issues also represents an area where there is potential for future work to be completed.

The Solidworks to Mathcad add-in problem also greatly affected progress for a large amount of time, as an alternative automation method had to be sought. Possible future work relating to this could involve the development of the Solidworks and Mathcad add-in for the current program editions. Developing this add-in would completely eliminate the use of excel within the program, and would improve the simplicity of the design. This enables the direct passing of data between Solidworks and Mathcad and would only require another user interface for it to operate successfully.

Another area that could be considered for a future design system would be the inclusion of other standards such as ASCE 7. This standard greatly complicated the automation system through the need to reference maps for data and consequently was omitted from design, but adding it to a future design would greatly enhance the system and would provide it with a much more accurate range of outputs. Other standards such as standards that cover the roof design could also be implemented, broadening the automation scope and providing a larger range of potential clients for CHSS.

New editions of API650 would also need to be considered. When a new edition is released the automation system would need to be comprehensively reviewed, checking all calculations for changes. A small change in a formula could result in a tank failure if the automation system went unchanged, and this could mean a loss of reputation, revenue and possible prosecution for poor tank design.

If these recommendations can be implemented into future work then it is believed that the API650 Tank design automation system could become a viable choice in the tank design industry, with the short time taken to produce the outputs being a driving factor in its success.

5. Acknowledgements

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