Flowmaster
Fluid thinking for systems engineers

Case Study

Process

Spectrum Fluid Dynamics

Fluid thinking for process - Spectrum Fluid Dynamics.

Spectrum Fluid Dynamics are consultants in surge and pulsation analysis with experience of measurement and simulation techniques to address surge and pulsation problems both remedially and at the design stage. Our past projects have spanned the process, utility and petrochemical industries, working for engineering contractors, machinery manufacturers and end-users throughout the world.

Spectrum use Flowmaster software for all of their surge analysis applications. The software was recently used at the design stage of a project for a major European engineering contractor. The project involved the design of an LNG loading system which forms part of a major petrochemical plant in the Middle East.

Two systems were studied. The first was the system that pumps LNG from storage tanks through a pipework system, including loading arms, to tankers. The second was the cooling water system that serves the heat exchangers associated with various on plant processes.

The aim of the project was to analyse the surge effects of the possible transient events such as valve closure, pump trip, pump start up and heat exchanger tube rupture, ensuring that both the associated pressures and

forces were within the system limits. To analyse the forces on the pipework, Spectrum developed post-processing software that takes the output created by Flowmaster and calculates the net forces acting along pipe runs caused by the transient pressures within the pipework.

LNG Loading System Analysis

The LNG system analysis investigated the surge effects associated with two shutdown systems and also partial failure of the shutdown systems. The first system trips the loading pumps (of which there are 8 in total), opens the pump recycle valves, shuts down the main valves in the loading lines over 15 seconds, shuts down the valves at the loading jetty and also at the ship. The second system shuts down the valves at the loading jetty, leaving the pumps running in recycle mode.

In addition to checking system pressures and forces Spectrum were required to recommend closure times for the main valves and the required time delay between the closure of the main valves and the loading jetty valves. Recommendations for any Surge Drum or Surge Relief Valve requirements were also specified.

The initial analysis highlighted four problems in the system:

- The closure of the main loading line valves causes cavities to form downstream of these valves. The subsequent collapse of these cavities causes excessive pressure impulses in the system.
- As the pumps trip, cavities form downstream of the pump non-return valves. The subsequent collapse of these cavities causes high pressure impulses that exceed system limits.
- Closure times of 3, 5 and 7 seconds were analysed for the jetty head valves. With the closure time set to

3 seconds the system pressure limits were exceeded.

- Closure of the ship's valve over 15 seconds, as specified, causes pressures in excess of the system limits upstream of the valves.

To solve problem 3 a valve closure time of 5 seconds was recommended.

To solve problems 1 and 4, changes in the timing of the valve closures were recommended. In terms of surge pressures, the most critical part of a valves closure is the last third, and it is this part of the closure that controls the subsequent pressures upstream and downstream of the valves. It was therefore recommended that the closure of these valves is carried out in two stages whilst maintaining the overall closure time. In the case of the main loading line valves, it was recommended that the first two-thirds of the valve closure is carried out over 5 seconds, with the remaining third being carried out over the next 10 seconds. For the ship's valve it was recommended that the first 90% of the valve closure should take 5 seconds, the remaining 1-0% being carried out over the next 10 seconds. With these timings in place the system pressures and forces are within the system limits.

To solve problem 2, the cavities should be prevented from forming downstream of the non-return valves (NRVs). If the cavities only form upstream of the NRVs, they are isolated from the forces that could cause the cavities to collapse, most importantly from the pumps that do not trip. Two options were investigated to solve this problem.

The first was to move the non-return valves further downstream and at a lower elevation. With this option in place, the cavities only form upstream of the NRVs. The second option was to add a surge drum to the system. This adds fluid to the system in the region of the NRVs when the pressure falls below a set level, ensuring that the system pressure does not fall below vapour pressure and cavities do not form.

Moving the NRVs is likely to be a lower cost option than the installing a surge drum, therefore this option was recommended.

Seawater Cooling System Analysis

In the seawater system there are three pumps and the system is generally run with two operating and one on standby. Pump trip was investigated, and the system is designed such that the standby pump starts up upon trip of a pump. Closure and opening of the isolation valves downstream of the pumps was also investigated, as was the simultaneous trip of two or three pumps (caused by power failure), with no standby pump start up. Heat exchanger tube rupture was also investigated.

The initial analysis highlighted two problems in the system:

- Pump trip causes vapour cavities to form at the high points of the system around the heat exchangers. The subsequent collapse of these cavities causes extremely high pressures, significantly exceeding the system limits.
- Rupture of heat exchanger tubes carrying process gas causes excessive pressures in the cooling water side of the heat exchangers.

To solve the tube rupture problem a bursting disc solution was designed, being sized such that the pressure limits of the heat exchanger and the system piping were not exceeded.

A number of possible modifications were investigated to solve the vapour cavity problem. Cavities tend to form at high points in systems and also downstream of points of loss of head. In this system the high elevation points coincide with the points of loss in head from the heat exchangers and its orifice plates, which are used to control flow. Surge pressures could therefore potentially be reduced by reducing the height of the heat exchangers and/or moving the associated orifice plates to positions of low height. However, it was considered impractical to alter the height of the heat exchangers and even with the orifices at their lowest possible location, cavities will still be formed and additional measures will be required to control them.

The remaining options for controlling such cavity growth and collapse were the use of surge drums or vacuum breakers. Vacuum breakers are not a recommended solution for this system. If they were used, any pump trip scenario would lead to vacuum breakers letting air into the system and this would also cause the heat exchangers to trip. In addition, the use of vacuum breakers would necessitate substantial re-priming of the system to remove air before it can be re-started after any pump trip scenario. We therefore considered surge drums as the preferred option to solving this problem. A large surge vessel was therefore designed which adds fluid to the system as the pumps trips, preventing the vapour cavities from forming.