MORKO Ultrasonic Scale Prevention Technology

Acceptable Ultrasonic Vibration and Sound Emission Levels

MORKO USP systems extend the run-time between cleaning intervals for pipes, unfired heat exchangers and some fired heaters. Candidates include, but are not limited, to CDU, HVU, FCCU, along with ethylene and other polymer processing units. USP has been effectively demonstrated in exchangers where the fouling is soft/gel; hard crystalline formation; asphaltene; and in applications where hard, brittle mineral scale precipitates and forms on the heat transfer surface.

This document provides information relevant to the resolution of previously raised technical concerns regarding safety and integrity risks to the equipment, where the USP system is being applied.

Additional information regarding USP system specifications, installation parameters and instruction, you can consult the **ORANGE Cleantech: USP Installation and Maintenance Guidelines** doc.

1. TECHNICAL FAQ

This section addresses resolution to previously raised technical concerns regarding safety and integrity risks to piping and heat transfer equipment using the MORKO, USP system.
In 2012, Shell Global Solutions Inc., conducted specific FEA testing, to fully understand the effects of USP upon the equipment receiving this MORKO technology.

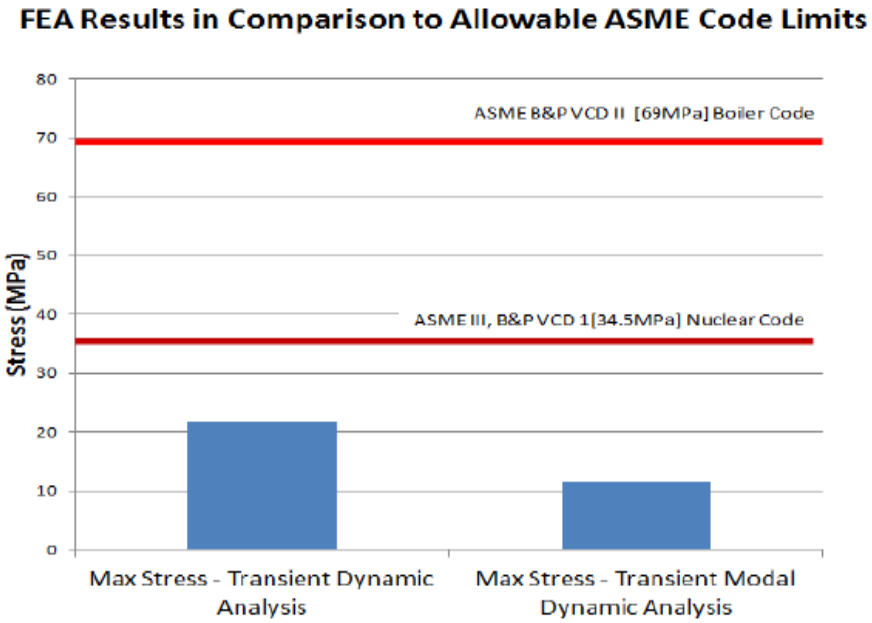
1.1. Addressing the Potential for Fatigue Damage

1.1.1. For the H-21102A fired heater application at Shell Scotford in Alberta Canada, an FEA analysis was completed modeling the geometry of this application and accounted for the amplitude and frequency of vibration induced by the USP system. The results of the FEA showed ultrasonic vibration emitted from USP transducers are less than 5µm. These results of the FEA confirm that fatigue damage due to USP vibration was not a concern since the stress induced by the USP system is below the threshold values based on two ASME references:

(1) ASME Boiler & Pressure Vessel Code Division II states that for Nickel-Chromium Molybdenum-Iron material operating at temperature not exceeding 427°C (800°F), the lowest stress level considered in the fatigue curve coefficient is 103.5 MPa (15 ksi). At the location where the largest maximum principal stress was observed, the temperature was around 500°C. To be conservative, a lower threshold value of 69 Mpa (10 ksi) was considered due to the higher temperature.

(2) ASME III, Boiler & Pressure Vessel Code, Division I Subsection NH, 2004 regulates construction of nuclear facility components. The estimated fatigue limit for 316 SS at 650°C (1200°F) would be 34.5 MPa (5 ksi). This reference is specifically for high temperature materials.

***Finite element analysis** (**FEA**) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. **Finite element analysis** shows whether a product will break, wear out, or work the way it was designed.*



The figure above shows that the maximum stress of 21.9 MPa for the transient dynamic analysis from the FEA is below the ASME reference limits. Further, the stress-strain curve for 316SS shows that the elastic range extends from 0 – 190 MPa. The maximum stress for the transient dynamic analysis from the FEA was well with the elastic range.

1.2. Addressing the Potential for Cavitation Corrosion Damage

1.2.1. Scientific literature suggests that cavitation corrosion can take place where fluids in contact with metal (especially water) are exposed to ultrasonic vibrations. However, accurate monitoring of corrosion rates was taken while demonstrating the USP system on the FAME test rig. The experimental data showed that corrosion rates were low and within the industrially accepted range for this service which tested crude oil.

USP can be recommended for plant use, with a monitoring or inspection plan, that may be a baseline and a subsequent inspection after a pre-determined number of hours in operation. Further inspections must be structured on a Risk Based Inspection methodology. For water applications, it is recommended to monitor corrosion rates using corrosion coupons to ensure USP systems are not causing corrosion issues in the heat exchangers.

1.3. Addressing the Potential for Fretting Damage

1.3.1. Flow induced vibration resulting from high shell side velocity in exchangers can cause dynamic interactions between tubes and tube supports resulting in fretting damage.

Acceptable amplitudes of tube vibration are provided in Shell DEP 31.21.01.12 Section 2.9.6, which aligns with recommendations by HTRI and TEMA.
In this section of the DEP, the tube amplitude due to vortex shedding is limited to not exceed either 10% of the tube ligament or 2% of the tube outside diameter, whichever is less.

As an example, consider a typical 1" OD heat exchanger tube. 2% of the tube outside diameter is 0.02" (0.02 * 1") and 10% of the tube ligament with a typical 1.25" pitch would be 0.025" (0.1 * (1.25" – 1")). Therefore, the acceptable amplitude due to vortex shedding to ensure that tube damage will not take place is the lower of these values, 0.02". This amplitude is considerably less than the expected tube vibration of 0.000189" (< 5 microns) which occurs due to operation of a USP system.

1.4. Potential Damage to Pipes, Gasket Seals, and Loosened Bolts

1.4.1. USP technology has been applied in Crude Distillation Unit exchangers E-115 and E-118 exchangers at Tabangao Refinery. After 48+ months of operation, no evidence of damage to the tube bundles, flanges, bolts, gaskets, or associated heat exchanger piping was observed while operating with the USP system online.

1.4.2. Five (5) months of testing were performed at the FAME pilot test rig in Bangalore using crude oil. At the conclusion of this testing, inspections were performed and showed no damage to the tubes, flanges, bolts, gaskets, or associated heat exchanger piping.

Shell has conducted further analysis and positive USP results have been realized in actual field testing at Shell Locations:

Tabangao Refinery – USP technology has been applied in the CDU (Crude Distillation Unit) exchangers on E-115 and E-118 exchangers. Currently, 53 months on continuous test with outstanding results. USP has had a 90% reduction in fouling on one of the two test heat exchangers. No evidence of damage to the tube bundle, flanges, bolts, gaskets, and associated heat exchanger piping.

Bangalore Test Labs – FAME Pilot Scale Testing – 5 months of testing which concluded in 2012. USP testing shows total elimination of fouling at fluid velocities above 1.0m/s over a several week period. Inspections have shown no damage to the tubes, flanges, bolts, gaskets, and associated heat exchanger piping.

Outside of the Shell organization:

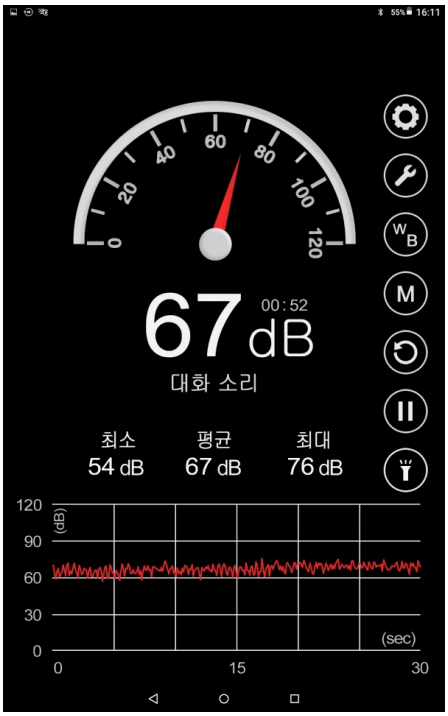
PTT (Thailand's State Owned Petroleum Company) - 2100-E3A/B Dependantizer – Reboiler Exchanger – This USP application realized a fuel savings of ~$1.3 Million per year by reducing fouling on the heat transfer surface.

Singapore Refining Company - 5803CECF Visbreaker – this application showed a 40% reduction fouling rate and realized a significant decrease in cleaning and downtime opportunity costs over the course of operation.

Sound Level Safety concern of MORKO Ultrasonic scale preventer (USP)

To date, we have successfully completed more than 1000 installations globally, of our Ultrasonic Scale Prevention system. Installation locations include Exxon, GS Caltex, PTT Global, Samsung, Hyundai and for the operations of Shell Global, including their plant in Pernis, Netherlands. There have been no safety issues.

For USP, the ultrasonic wave frequencies have been measured with specified equipment, to levels between 67 and 69dB as recorded. This is well within the time weighted exposure of 85dB (EU-OSHA) for an 8 hour shift.



While the 'clicking-sound' emanating from the transducers does readily comply with EU-OSHA industry requirements and does not pose a safety risk given that site specified hearing protection recommended— we do recognize that this sound is not pleasant to some people.

Please ensure all site personnel comply to wearing the proper protective equipment when in a processing unit where USP is present.

Jong-Wook Chae
President,
Morko International

EU-OSHA
*The Occupational Safety and Health Administration's (OSHA's) Noise standard (29 CFR 1910.95) requires employers to have a hearing conservation program in place if workers are exposed to a time-**weighted average** (TWA) noise level of 85 decibels (dBA) or higher over an 8-hour work shift.*

For any additional information you may require, please feel free to contact an ORANGE Cleantech representative and we'll be pleased to assist you with your query.

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