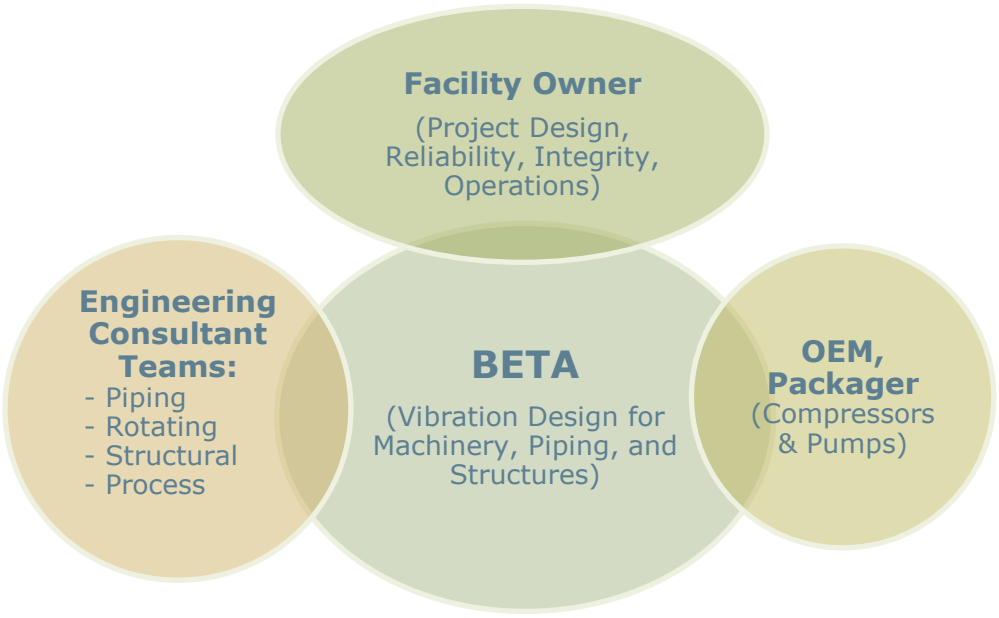
Specification: Facility Wide Vibration Design Requirements (Greenfield and Brownfield Projects)

Background

Vibration-related reliability and integrity problems exist on onshore and offshore production facilities. To manage these risks, the appropriate engineering work is required at the design stage. This specification includes the piping system and relevant rotating/reciprocating machines and enables owners to address vibration across the entire facility.
For superior results, BETA work directly for the owner and would be involved at the FEED/Planning stage to provide recommendations as to which machines require attention (and which ones don't), layout ideas, and design approaches. This will ensure the vibration design is aligned with the owner's operational, reliability, and integrity requirements.

The engineering work must be integrated with other team members (owner, EPC teams, OEMs, and packagers). The chart below illustrates our role in integrating the design and inspection recommendations. This approach avoids the common design gaps that result in vibration, reliability and integrity problems.



BETA is an important member of your team. We address the specialty vibration/dynamic engineering requirements that affect different aspects of the design and inspection process.

Goal

Achieve the organization's reliability and integrity goals for the production facility, including the mitigation of vibration and dynamic issues on platform structures, machinery, and piping system.

Approach

An integrated and coordinated approach is required to manage vibration on a platform. This approach will ensure the appropriate scope of work is conducted at the right time and involves input and review by the necessary stakeholders. See BETA's article, *An Integrated Approach to Manage Vibrations Risks*, available as a pdf download on our website, BetaMachinery.com

Vibration Considerations/Requirements

The following scope of work is typically required for a production facility that includes reciprocating and rotating loads, and integrity risks associated with piping vibration.

To ensure consistency and avoid conflict results, the scope of work should be performed by the same vibration engineering firm. For more detailed specifications for individual machine or piping assets, refer to our website, BETA Machinery.com/Specifications.

For application questions, contact us, info@betamachinery.com.

DETAILED DESIGN STAGE

The following is a summary of the type of engineering requirements necessary for a large production facility. This list provides an overview of the requirements; more detailed specifications are available as pdf downloads on our website, BetaMachinery.com.

Overview of Considerations

1. **Reciprocating Compressors and Pumps**
   a. Pulsation and Mechanical Analysis – For compressors (per API 618, DA3 and GMRC High Speed Guideline) and pumps (API 674). Time Domain acoustical analysis required based on approved simulation software. MAPAK software approved. Frequency Domain simulation software not acceptable. Mechanical Analysis must include Frequency Avoidance and Forced Response Analysis using ANSYS software. Significant forces to be calculated and applied to the analysis include pulsation forces, cylinder gas forces, cross head forces, unbalanced forces, torsional to lateral forces, etc. Results to be analyzed across all operating conditions using BETA's DataMiner software.
   b. Torsional Vibration Analysis to include all normal conditions, start-up, transient, upset and conditions across the full speed range. Results to be assessed using BETA's DataMiner software.
   c. Pipe Stress Analysis often required for larger station/facilities.
   d. Small Bore Connection (SBC) Assessment required.
   e. Skid Design and Analysis, Foundation Design and Dynamic Analysis, Lifting and Environmental Loading Analysis for reciprocating compressor package.

2. **Centrifugal Compressors - Surge Control Dynamic Analysis**
   The scope of the proposed dynamic study includes these steps:
   a. Recycle system. Assess the recycle system capacity with respect to the compressor wheel map. Confirm the size/capacity (adequacy) of the system for the steady state operating range. Include modeling the compressor, piping system, and valve characteristics.
   b. Start-up protocol. Assess the system start-up sequence and evaluate discharge temperature versus time.
   c. Normal shutdown protocol. Assess the normal shutdown protocol to evaluate the valve shutdown sequence, timing, rates, and the driver ramp down (turbine, motor, engine, etc.).
   d. Slow Transients Analysis. Provide independent check of the compressor surge control protocol during slow transient events such as inadvertent closure of suction and/or discharge valves (e.g., accidental shutdown).
   e. Fast Transient Analysis. Due to Emergency Shutdown (ESD), fast stop, or power failure; evaluate entire system and effectiveness of recycle system in severe dynamic conditions.

   CENTRAN transient analysis simulation software to be used for analysis.
   The deliverables include recommended changes to the control logic, recycle strategy, and other parameters, and report defining surge control characteristics during upset conditions and across the operating window.

3. **Foundation or Structural Dynamics/Vibration**
   Analyze and provide recommendations to avoid resonance from reciprocating and rotating loads. This includes a Frequency Avoidance and Forced Response Analysis with the following factors:
   a. Include all excitation loads such as pulsations and unbalanced forces throughout compressor piping system
   b. incorporate all machinery on platform including reciprocating compressors, centrifugal compressors, gensets, and pumps
   c. Integrate the pulsation and mechanical models (per 1.a. and b., above) into the dynamic structural model to ensure accurate excitation forces and boundary conditions

d. Use ANSYS software for the Forced Response Analysis
e. Consider worst case vibration interaction between machines
f. Use BETA's DataMiner software for specialized data reduction techniques to assess individual machines (operating conditions, locations, frequencies) and across multiple units

4. **Piping Vibration and Integrity** – including the following
   a. Flow-induced vibration (FIV), flow-induced turbulence (FIT), and acoustic-induced vibration (AIV) design review for centrifugal and associated piping system
   b. Small Bore Piping/Connections design review for all facility piping
   c. Piping Vibration and Integrity Assessment per Energy Institute Guideline (2008
   d. Pipe Stress Analysis (thermal piping flexibility analysis) for vibratory loads: For applicable piping system include dynamic/vibration issues as well as thermal design requirements. This includes modifications to the proposed piping layout, piping restraints and support designs.
   e. Transient Vibration Analysis for Gas Systems per Energy Institute Guideline 2008
   f. Water Hammer Analysis for liquid systems

COMMISSIONING AND INSPECTION

1. **Piping Vibration Assessment**
   - Main piping assessment
   - Small bore connections and piping
   - Field based assessment to static and transient testing using multi-channel data acquisition (>100 channels) and hand held test equipment. Advanced testing includes relative vibration, finite element analysis (FEA), stress measurements, etc.

2. **Reciprocating machines**
   Pulsation and vibration baseline on compressor, driver, skid, vessels, and cooler; includes verification of pulsation amplitudes, mechanical natural frequency (MNF) testing on cylinders, vessels, and pulsation control devices.

3. **Foundation**
   Baseline vibration measurements compared to guideline

VENDOR QUALIFICATIONS

Beta Machinery Analysis (BETA) is approved as a qualified vibration engineering firm. Other firms must be approved by the owner.
Vendor is to supply documentation to confirm their capabilities and experience.
Below is a summary of BETA's capabilities and experience

a. BETA has a design and field office in SE Asia.
b. Overall design team includes over 50 trained engineering experts in vibration design. Principal engineers and Senior Engineers manage teams specialized in:
   i. Dynamic structural analysis
   ii. Pulsation and mechanical machinery analysis
   iii. Piping vibration and stress analysis
   iv. Small bore piping/connection design and field testing
   v. Transient and surge simulation studies
   vi. Vibration troubleshooting
c. Own and have 10 years of experience in operating the following simulation software:
   i. MAPAK, time domain acoustical and mechanical software
   ii. CENTRAN, transient analysis simulation software
   iii. ANSYS, finite element software
   iv. CAESAR II
   v. DataMiner post-processing software for dynamic studies
d. Own and have 10 years of proven experience in field testing, troubleshooting, and inspections:
   i. RecipTrap for compressor analysis

ii. Zonic hardware and software data acquisition system with over 100 channels of transducers
iii. Data Physics (Quattro) for pulsation and mechanical analysis field testing
iv. MHealth rotating performance monitoring and assessment software
v. ME Scope for modal analysis

e. Field troubleshooting and inspection engineers:
i. Over 15 dedicated field analysts (employees, not contractors)
ii. Audited safety program
iii. Staff trained in pulsation analysis, small bore piping assessments, modal analysis, torsional analysis