Structural Analysis with Reciprocating Compressors

There are several critical aspects of reciprocating compressor analysis methods for offshore deck structures that are not obvious. The following are major items that typically are not completed:

- Platform super structure and decks are normally included in the structural model; however, the equipment package skids are not included as structural members. The skid are only included as joint loads and/or beam loads.

- Calculations of unbalanced forces from mechanical sources and gas compression. All compressor manufacturers only supply mechanical unbalanced forces and do not offer crosshead forces due to gas compression.

- Typically, structural stress analysis FE models utilize area loads for skids mounted on the deck. While this approach is suitable for stress analysis, it creates large errors in dynamic analysis results.

- Engine driven compressors have an operation range from 800 – 1200 rpm, which is a 33% spread. For a complete analysis, natural frequencies should be analyzed at 1X and 2X the operating range because the compressor unbalanced forces occur at these frequencies. Often, dynamic analysis is only completed for 1X the operating range and the 2X is not addressed.

- Based on field experience, structural natural frequencies can be partially excited. Natural frequency locations should include a sufficient margin away from the operating ranges to prevent partial excitation.

- Compressor skids and their supporting decks should be designed with proper energy paths to transmit unbalanced forces through the skid, into the deck and into the major truss framing. Otherwise, the unbalanced energy will create vibration problems on the compressor package. Most structural designers are unaware of structural energy paths.

Deck & Skid Analysis Methods

- All package skid beams should be included in platform or FPSO deck dynamic analysis models. If not, the combined stiffness of the deck and equipment skids will not be correct. The natural frequencies of the combined structures cannot be simulated properly unless all the structural components (including package skids) are included in the structural model. If separate dynamic analysis is run on the compressor package skid, the dynamic natural frequencies will be inaccurate because the mounting stiffness is incorrect. The stiffness of the deck alone cannot be utilized because the skid will add significant stiffness in the local deck area.

- The crosshead unbalanced forces from gas compression are 3 – 8 times the typical mechanical unbalanced forces given by compressor manufacturers. In addition, the compressor unbalanced forces should be phased for each set of cylinders. These factors make a very large difference when analyzing skid and deck vibration.

- Loads from the equipment on each package skid should be modeled as individual joint or beam loads on the skid beams. If not, the localized stress and dynamic energy paths will not be correct. This is a critical factor necessary to insuring accurate vibration amplitudes with forcing functions.

- Proper attachment of reciprocating compressor skids in very important. Typically there are 40 to 50 attached points where the skid beams should be welded directly to the platform deck beams. If these support points are modeled correctly, the combined deck-skid stiffness and natural frequencies will change. In addition, the energy from unbalanced forces will not flow out of the skid and will cause excessive vibration on the skid beams.

- Multiple compressor installations on a deck present various complex problems because of their unbalanced force phasing in relation to each other. The compressor phasing between machines is random and based on when the operator starts the machinery. In addition, phasing of engine drivers is continuously changing. Therefore, it is necessary to complete the vibration analysis by evaluating different compressor unbalanced force phasing for each compressor in relation to each others.

- The structure model should be large enough to define the major deck support stiffness. On an offshore platform, this requires modeling of all the topsides super structure because legs, vertical deck supports and diagonals significantly affect the localized deck stiffness. On FPSOs, the ship’s deck stiffness, stool design and deck-to-stool attachment methods significantly affect localized deck stiffness.

- When dynamic vibration problems have been analyzed, a practical solution is not always evident. Without field vibration analysis experience, it is extremely difficult for a design engineer or analyst to understand the nature of reciprocating compressors. Common vibration problems and their practical solutions are not readily known or available. However, Tech Transfer has been exposed to many of these problems during their extensive field vibration analysis experience and has developed practical solutions.

TECH TRANSFER WILL NOT CONDUCT AN INDEPENDENT DYNAMIC ANALYSIS OF RECIPROCATING COMPRESSOR SKIDS WITHOUT INCLUDING THEM IN A COMPLETE PLATFORM STRUCTURAL MODEL OR A FPSO DECK MODEL WITH STOOLS AND SHIP’S HULL STIFFNESS.