**Gas Field Policy 21:** Torsional Vibration Analysis

# TORSIONAL VIBRATION ANALYSIS OF SIEMENS ENERGY HSRC COMPRESSORS AND DRIVING MACHINERY

Siemens Energy, upon request, will act as a consultant and perform a torsional vibration analysis of the separable drive system. Please refer to the appropriate price page for the cost of this service.

Siemens Energy's responsibility is limited to providing a proper engineering torsional analysis. The responsibility for engineering of the system components (other than the compressor), and the supply of these components must remain with others.

The analysis will either confirm satisfactory torsional operation of the system as submitted, or it will recommend the changes that need to be made to the shafting system for satisfactory operation over the conditions specified by the customer.

The torsional vibration analysis is not intended to check or give approval to the transmission shafting in such areas as sensitivity to misalignment or any other engineering aspect connected with the selection, mounting, and operation of a separable compressor and its driving machinery. The responsibility for satisfactory engineering in these areas is outside Siemens Energy's scope of responsibility.

The following guidelines are to better define when a torsional analysis is required:

I. Torsional Analysis Study Requirement

A. A torsional study is required when a separable compressor is driven; by a turbine or engine through a gear; or by any motor.

B. A Siemens Energy HSRC compressor directly coupled to an engine driver does not require a torsional analysis if the coupling is selected based on the maximum BHP capability of the compressor or engine frame, whichever is less (rather than the maximum BHP of the specific compressor application). In this case the mass elastic properties of the system will be sufficient to provide torsional stability.

C. If the coupling is selected for less than the maximum BHP capability of both the compressor and engine frame and the compressor is directly coupled to an engine, then a torsional study will be required if the operating conditions of the unit fit into one or more of the following criteria:

1. Discharge pressure is higher than 1400 psig
2. Compression ratio is less than 1.8
3. Single acting cylinder is used for any condition
4. Two-in-one cylinder configuration is used
5. The ratio of tension and compression frame loads is more than 2.5 or less than 0.4
6. Large rod load and small BHP applications, where RLR (Rod Load Ratio) - HPR (Horsepower Ratio) is greater than or equal to 35.

$$RLR = \frac{\text{Compressor Rod Load}}{\text{Rated Rod Load}} \times 100$$

$$HPR = \frac{\text{Compressor BHP}}{\text{Rated Frame BHP}} \times 100$$

If no torsional analysis is required, the coupling selection can be based on the maximum BHP of the specific compression application. In this case, $WR^2$ is provided by the engine manufacturer's standard flywheel.

If a torsional analysis is required, the coupling selection and required flywheel $WR^2$, if any, will be determined by Siemens Energy at the time of the analysis.

The coupling used in any engine-compressor drive system must be torsionally stiff but be able to accommodate some axial misalignment. A suitable coupling is Thomas or equivalent.

II. Data Required By Siemens Energy For The Torsional Analysis

A. The complete operating performance envelope of the compressor including speed ranges and unloaded conditions.

B. The complete description of the drive train, including name of manufacturer(s), model numbers and diameters for the gear reducer and engine shafts, plus the tentative coupling selections.

C. The $WR^2$ of the motor rotor, and shaft drawings of the driver and gear reducer rotating parts. The driver shaft drawing must include the keyway dimensions, including radius, and shaft material including ultimate tensile strength.

D. The method of unloading the compressor for start-up. (If bypass, pipe sizes are required.)

E. All information of the driver and shaft system must be supplied by the customer to Siemens Energy. A completed "Torsional Analysis Information" form (see GFP-1) must be a part of the order.

III. SCOPE OF TORSIONAL ANALYSIS

A. The scope of Siemens Energy's analysis is to select the proper flywheel $WR^2$ (if required) and coupling stiffness, to ensure safe unit operation. Turbine or engine driven unit operation will be investigated, over the customer's specified speed range, for the presence of any critical speed at which the unit operation would be unsafe.

B. The torsional analysis studies the effects of the compressor torque on the mass-elastic system of the entire drive system. It is not intended to study vibrations (lateral or torsional), within the gears or between the gear reducer and turbine, generated by gear irregularities, since these types of vibration must be investigated by the gear manufacturer, during the design stage.

C. Shutdown of the unit under no-load and vented conditions is permissible in any system, and is therefore not a part of this study.

D. For direct drive motor units, the vibratory stress in the motor shaft will be evaluated to check that it is in a safe range according to Siemens Energy standards.

IV. MOTOR DRIVER RECOMMENDATIONS:

A. Motor shaft diameter should be as large as possible with the minimum acceptable diameter (anywhere on the shaft) determined by the following formula:

$$\text{minimum shaft dia. (in)} = \sqrt[3]{\frac{107 \text{ X (motor nameplate HP rating)}}{\text{RPM}}}$$

B. The ultimate tensile strength of the motor shaft material should be 75,000 PSI minimum.

C. If the above motor shaft recommendations are not followed, and the analysis determines that the submitted shaft is not suitable, additional charges for further study will be applicable.

D. The motor manufacturer must be advised that the motor will be driving a reciprocating compressor which is a severe duty and must be designed suitable for the following vibratory torques:

| | |
|---|---|
| 2 throw compressor | +/- 200% Motor nameplate torque |
| 4 throw compressor | +/- 175% Motor nameplate torque |
| 6 throw compressor | +/- 150% Motor nameplate torque |

This means that for a motor driving a 2 throw compressor the motor must be suitable for a torque variation within each revolution of a mean torque equal to nameplate torque,maximum torque equal to positive 300% of nameplate torque and minimum torque equal to negative 100% nameplate torque.

E. The motor shaft should be designed without a keyway. If the shaft is designed with a keyway full details of the design must be included with the shaft information supplied to Siemens Energy.

F. The prime mover HP must include allowance for the tolerance on compressor BHP (See GFP2). Failure to adhere to this practice may prohibit unit operation at full load. It is further recommended that prime movers be selected in accordance with ISO-13631: 2002 Section 8.

G. Adherence to these guidelines may reduce the need for a flywheel under certain conditions of service, or possible rejection of the motor.

H. For reference, motor suppliers should use the following inertia values when determining breakaway torque requirements. This data represents the highest inertia that could be encountered for the given frame.

| **Compressor Size & Type** | **Inertia (lb-ft2)** | | **Compressor Size & Type** | **Inertia (lb-ft2)** |
|---|---|---|---|---|
| 5 - MOS 2 | 60 | | 7 - HOS 2 | 165 |
| 5 - MOS 4 | 95 | | 7 - HOS 4 | 290 |
| 5 - MOS 6 | 135 | | 7 - HOS 6 | 370 |
| 6 - MOS 2 | 85 | | 5 - HOSS 2 | 210 |
| 6 - MOS 4 | 135 | | 5 - HOSS 4 | 315 |
| 6 - MOS 6 | 185 | | 5 - HOSS 6 | 400 |
| 7 - MOS 2 | 115 | | 6 - HOSS 2 | 270 |
| 7 - MOS 4 | 185 | | 6 - HOSS 4 | 400 |
| 7 - MOS 6 | 250 | | 6 - HOSS 6 | 505 |
| 5 - HOS 2 | 115 | | 7 - HOSS 2 | 345 |
| 5 - HOS 4 | 175 | | 7 - HOSS 4 | 505 |
| 5 - HOS 6 | 230 | | 7 - HOSS 6 | 635 |
| 6 - HOS 2 | 135 | | | |
| 6 - HOS 4 | 215 | | | |
| 6 - HOS 6 | 285 | | | |

V. TORSIONAL ANALYSIS REPORT

When Siemens Energy performs a Torsional Vibration Analysis, the standard report will contain the following information:

A. Compressor crank effort

B. First and second mode critical speeds

C. Resonant speeds for first and second node mode of vibration

D. Mass elastic information

E. Mass elastic curve for first and second node mode of vibration

F. Vibratory stress vs. speed curve

G. Forced vibration analysis

H. Current pulsation analysis (electric motor drive only)

I. Selection of coupling and flywheel (lb-$ft_2$, if flywheel is required)

J. The following disclaimer:

The recommendations and predictions contained herein represent Siemens Energy's best Engineering judgement, based on the information available to Siemens Energy. In offering these recommendations, no warranties or guarantees of any nature are expressed or implied. Any decisions made and/or work performed as a result of said recommendations shall be at the entire risk of the user.

Siemens Energy shall in no event be liable to the Purchaser, any successors in interest or any beneficiary of an order or contract for any consequential, incidental, indirect, special or punitive damages arising out of the contract or any breach thereof, whether or not such loss or damage is based on contract, warranty, negligence, indemnity, strict liability or otherwise.

The liability of Siemens Energy with respect to an order or contract shall not exceed an amount equal to the contract price paid by the Purchaser.