CHOOSING THE RIGHT TORQUE SENSOR

TOPICS COVERED
Determining Maximum Average Running Torque
Determining Probable Peak Torque
Accounting For Starting Conditions
Satisfying Accuracy Requirements
Avoiding EMI/Noise Errors
Specifying Input Power And Output Signals
Assuring Calibration Accuracy

S. HIMMELSTEIN AND COMPANY
CHOOSING THE RIGHT TORQUE SENSOR

**Step 1. Find the Maximum Average Running Torque (MART).**
The equation finds the maximum average running torque (MART). For rpm, use the lowest speed at which maximum rated power is developed.

\[
\text{MART (lbf-in) = [Max Rated Horsepower] X (63025) / [rpm]}
\]

**Step 2. Estimate the Probable Peak Torque (PPT).**
Rotary machinery exhibits pulsating or smooth torque. Peak stress determines shaft capacity not stress duration (except for fatigue). To find a conservative value of probable peak torque:

1. This procedure will select a conservatively sized sensor. Analytical techniques can derive a more precise value of peak torque. However, they are dependent on having exact values for all significant shaft network parameters — seldom available.

Select the load service factor (LSF) from the following groups:
- LSF = 1 for smooth, constant load devices; fans, can fillers, centrifugal blowers & liquid pumps, axial compressors, etc.
- LSF = 2 for non-reversing, non-constant load or start/stop devices; extruders, hoists, conveyors, kilns, mixers, etc.
- LSF = 3 for high variable shock or light reversing loads; crushers, hammer mills, single cylinder reciprocating pumps, tree barkers, vehicle drivelines, etc.
- LSF = 4 → 6 for heavy to full torque reversals (need not cause reverse rotation) or with undamped torsional vibrations in the operating speed range; single and double acting reciprocating compressors, etc.

Select the drive service factor (DSF) from the following groups:
- DSF = 0 for smooth turbine, dc motor, or three phase ac motor except variable frequency drives.
- DSF = 0.5 for gas engines with 8 or more cylinders, diesels with 10 or more cylinders, single phase ac motors.
- DSF = 1 for 6 cylinder gas or 8 cylinder diesel engines, three phase variable frequency ac motors.
- DSF = 1.5 for 4 cylinder gas or 6 cylinder diesel engines and single phase variable frequency ac motors.
- DSF = 2 → 4 for gas engines with less than 4 & diesels with less than 6 cylinders.

Probable Peak Torque (PPT) = (MART) X (LSF + [DSF])

Select a sensor with overload rating = > 2 X PPT.

**Step 3. Check Starting Conditions.**
If the driver is an induction motor started across the line, and the load has high inertia, then verify the sensors’ torque overload rating is at least twice the motors’ rated starting torque. Alternately, use reduced voltage starting or limit motor current to reduce starting torque to the PPT calculated in step 1.

**Step 4. Check For Extraneous Loads.**
Any load, other than torque, is extraneous. Extraneous loads can be:
- axial, i.e., the weight and thrust of a vertical pump.
- radial, i.e., belt tension load.
- bending, i.e., a pulley sensor with a non-centered pulley.

When such loads are expected, verify they are within the sensors ratings. If they are not, consider re-arranging the installation to isolate those loads or to make the installation more tolerant of them. For example, a flat flanged torque meter can handle many times the axial load of a foot-mounted shaft sensor. Pulley torque meters handle large radial and bending loads unacceptable to other types.

**Step 5. Verify The Speed Rating by noting the sensor maximum operating speed.**

**Step 6. Verify Sensor Accuracy.** The acceptable error (%)

\[
\frac{\text{error}}{\text{scale}} = \frac{\text{nonlinearity}^2 + \text{hysteresis}^2 + \text{non-repeatability}^2}{2}
\]

Nonlinearity, hysteresis, and non-repeatability are sensor errors (% of full scale). If the calculated error is too high, use a higher accuracy grade or two or more sensors (or dual range sensors) for the test range.

**Step 7. Specify The Power Source.** Select from vehicle battery, other dc power, ac carrier amplifier, or ac power line.

**Step 8. Specify The Output Signal** from among ± 5V, ± 10V, mV/V, or the 4-20 mA, 2-wire transmitter, or digital formats.

**Step 9. Specify Noise Hardened Torquemeters** when EMI is present. This should always be done when IGBT-based adjustable speed and/or vector drives are used. If needed, use a zero velocity speed pickup. See Bulletin 708 for details.

**Step 10. Choose The Right Torque Sensor.** Select a sensor with a suitable mechanical configuration, meeting these criteria:
- full scale = > MART (maximum average running torque)
- overload = > 2 X PPT (probable peak torque)
- overrange = > PPT (probable peak torque)

If an external data acquisition system is used, its overrange must also = > PPT.

The margin between PPT and sensor overload is needed to avoid fatigue failure; never plan to operate there.

**Step 11. Verify The Torquemeter Is Accurately Calibrated And Meets Its Specifications.**
Your assurance is that the makers’ calibration laboratory is consistent with the sensor specification. That means its Cal Lab has an independent, internationally recognized accreditation* with a best uncertainty less than the torquemeter error spec. Clearly, it’s absurd to certify performance higher than the Cal Labs’ uncertainty — nonetheless, most competitors do and/or don’t have lab accreditation.

*Himmelsteins’ Torque Calibration Laboratory is accredited by NVLAP, an arm of the NIST, lab code 200487-0. Visit our website at www.himmelstein.com for a copy of the NVLAP Certificate and Accreditation Scope or, use the “Laboratory Accreditation” link at www.nist.gov
Excitation Power 10 to 32 V dc. Reverse polarity protected. Unregulated sources include battery power.

Mechanical Styles Flange. Shortest installed length.

Accuracy Grades Standard and Enhanced. NIST traceable calibration unaffected by cables.

Digital Filters 0.1 to 200 Hz in eleven 1-2-5 steps. User selectable through provided software.

Analog Output Signals ±5 V or ±10 V, filtered @ 1 & 500 or, 1100 Hz. Noise tolerant signal needs no amplification.

Excitation Power 10 to 15 V dc. Unregulated sources include battery power.

Mechanical Styles Shaft, flange, splined, pulley, roll, and wheel. Widest choice of standard products.

Accuracy Grades Standard and Enhanced. NIST traceable calibration unaffected by cables.

Excitation Power 11 to 24 V dc. Reverse polarity protected. Unregulated sources include battery power.

Output Signal ±5 V or ±10 V, filtered @ 1 & 500 or, 1100 Hz. Noise tolerant signal needs no amplification.

Required Cabling Simple three conductor shielded cable. Calibration and balance free of cable effects.

Accuracy Grades Standard and Enhanced. NIST traceable calibration unaffected by cables.

Mechanical Styles Shaft, flange, splined, pulley, roll, and wheel. Most popular styles are standard.

Excitation Power 3 kHz ±10% sinusoid @ 3-6 V rms, regulated. Good noise immunity for long cables.

Output Signal 1.5 to 4 mV/V rms, dependent on model. Matches 3 kHz strain gage carrier amplifiers.

Required Cabling Multiple twisted and shielded wire pairs. Complex cable needs reactive balance.

Accuracy Grades Standard and enhanced Best accuracy if calibrated with cable & amp.

Mechanical Styles Shaft, flange, splined, pulley, roll, and wheel. Widest choice of standard products.

Excitation Power 10.5 to 24 V dc. Reverse polarity protected. Unregulated sources include battery power.

Output Signal ±5 V & ±10 V, filtered @ 1 & 500 or, 1100 Hz. Noise tolerant signal needs no amplification.

Required Cabling Simple three conductor shielded cable. Calibration and balance free of cable effects.

Accuracy Grades Standard and Enhanced. NIST traceable calibration unaffected by cables.

Mechanical Styles Shaft, flange, splined, pulley, roll, and wheel. Most popular styles are standard.

Excitation Power 10 to 32 V dc. Reverse polarity protected. Unregulated sources include battery power.

Output Signal 4-20 mA @ 0 to 1100 ohms loop resistance. Has greatest immunity to ambient cable noise.

Required Cabling Simple two wire loop has lowest installed cost. Calibration and balance free of cable effects.

Accuracy Grades Standard and Enhanced. NIST traceable calibration unaffected by cables.

Mechanical Styles Shaft and flange types standard, others special. Most popular styles are standard.

Choose An MCRT® Digital, mV/V Or DC Operated Torquemeter, Or A 4-20 mA, 2-Wire Transmitter

<table>
<thead>
<tr>
<th>TYPE</th>
<th>SELECTION CRITERIA</th>
<th>MCRT® CHARACTERISTICS</th>
<th>COMMENTS/BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>mV/V Torquemeter</td>
<td>Excitation Power 3 kHz ±10% sinusoid @ 3-6 V rms, regulated.</td>
<td>Good noise immunity for long cables.</td>
<td></td>
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<tr>
<td></td>
<td>Output Signal 1.5 to 4 mV/V rms, dependent on model.</td>
<td>Matches 3 kHz strain gage carrier amplifiers.</td>
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<tr>
<td></td>
<td>Required Cabling Multiple twisted and shielded wire pairs.</td>
<td>Complex cable needs reactive balance.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accuracy Grades Standard and enhanced</td>
<td>Best accuracy if calibrated with cable &amp; amp.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mechanical Styles Shaft, flange, splined, pulley, roll, and wheel.</td>
<td>Widest choice of standard products.</td>
<td></td>
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<tr>
<td>DC Operated Torquemeter</td>
<td>Excitation Power 10.5 to 24 V dc. Reverse polarity protected.</td>
<td>Unregulated sources include battery power.</td>
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<tr>
<td></td>
<td>Output Signal ±5 V &amp; ±10 V, filtered @ 1 &amp; 500 or, 1100 Hz.</td>
<td>Noise tolerant signal needs no amplification.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Required Cabling Simple three conductor shielded cable.</td>
<td>Calibration and balance free of cable effects.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accuracy Grades Standard and Enhanced.</td>
<td>NIST traceable calibration unaffected by cables.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mechanical Styles Shaft, flange, splined, pulley, roll, and wheel.</td>
<td>Most popular styles are standard.</td>
<td></td>
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<tr>
<td>Digital Torquemeter</td>
<td>Excitation Power 11 to 24 V dc. Reverse polarity protected.</td>
<td>Unregulated sources include battery power.</td>
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<tr>
<td></td>
<td>Analog Output Signals ±5 V or ±10 V, user selectable.</td>
<td>Outputs Torque, Speed and Power (Option).</td>
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<tr>
<td></td>
<td>Digital Output RS232 Serial Port at 38,400 baud.</td>
<td>Fully-scaled engineering unit results.</td>
<td></td>
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<tr>
<td></td>
<td>Digital Filters 0.1 to 200 Hz in eleven 1-2-5 steps.</td>
<td>User selectable through provided software.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accuracy Grades Standard and Enhanced.</td>
<td>NIST traceable calibration unaffected by cables.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mechanical Styles Shaft, flange, splined, pulley, roll, and wheel.</td>
<td>Most popular styles are standard.</td>
<td></td>
</tr>
<tr>
<td>Compact Digital</td>
<td>Excitation Power 10 to 15 Vdc.</td>
<td>Unregulated sources include battery power.</td>
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<tr>
<td></td>
<td>Analog Output Signals ±5 or ±10 V, user selectable.</td>
<td>Outputs Torque.</td>
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<tr>
<td></td>
<td>Digital Output RS232</td>
<td>Fully scaled engineering unit results</td>
<td></td>
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<tr>
<td></td>
<td>Digital Filters 0.1 to 200 HZ</td>
<td>User selectable through provided software.</td>
<td></td>
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<tr>
<td></td>
<td>Accuracy Grades Standard and Enhanced.</td>
<td>NIST traceable calibration unaffected by cables.</td>
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<tr>
<td></td>
<td>Mechanical Styles Keyed Shaft</td>
<td>Inventory of standard units for fast delivery.</td>
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<tr>
<td>Bearingless Digital</td>
<td>Excitation Power 10 to 26 Vdc @ 10 W max.</td>
<td>Unregulated sources.</td>
<td></td>
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<tr>
<td></td>
<td>Analog Output Signals ±5V or ±10V, user selectable.</td>
<td>Outputs Torque.</td>
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<tr>
<td></td>
<td>FM Output 10 ± 5 kHz, 20 ± 10 kHz, 40 ± 20 kHz</td>
<td>Fully scaled engineering unit results.</td>
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<tr>
<td></td>
<td>Digital Output RS232/485.</td>
<td>User selectable through provided software.</td>
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<tr>
<td></td>
<td>Digital Filters 0.1 to 3000 Hz</td>
<td>User selectable through provided software.</td>
<td></td>
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<tr>
<td></td>
<td>Accuracy Grades Standard and Enhanced.</td>
<td>NIST traceable calibration unaffected by cables.</td>
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<tr>
<td></td>
<td>Mechanical Styles Flange</td>
<td>Shortest installed length.</td>
<td></td>
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<tr>
<td>4-20 mA 2-wire Transmitter</td>
<td>Excitation Power 10 to 22 V dc. Reverse polarity protected.</td>
<td>Unregulated sources include battery power.</td>
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<tr>
<td></td>
<td>Output Signal 4-20 mA @ 0 to 1100 ohms loop resistance.</td>
<td>Has greatest immunity to ambient cable noise.</td>
<td></td>
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<tr>
<td></td>
<td>Required Cabling Simple two wire loop has lowest installed cost.</td>
<td>Calibration and balance free of cable effects.</td>
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<td>Accuracy Grades Standard and Enhanced.</td>
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TORQUE SENSOR SELECTION EXAMPLES

Typical torquemeter applications are illustrated. They demonstrate important selection principles and criteria discussed in this document. Space limitations prevent an exhaustive treatment. Refer to Himmelstein Product Specifications, Installation Manuals and Technical Memoranda for additional details. You are encouraged to call if faced with a unique application or, should you need any help selecting a torque sensor. Our business is driven by solving your torque measurement and control problems.

Induction Motor Driven Axial Compressor. The 250 HP compressor is driven at 1,750 rpm by a 3 phase, 250 HP induction motor. From Equation 1, MART = 9,000 lbf-in. Since service is stop/start, the LSF = 2. DSF for the motor is 0. PPT = 9,000 X [2 + 0] = 18,000 lbf-in. The sensors’ overload rating = > 36,000 lbf-in. Since the torque signal will be used by the plant process computer 2,800 feet from the sensor, a 2-wire, 4-20 mA output format is desired. The compressor inertia is moderate and there are no significant extraneous loads. Choose either an MCRT® 39061X(12-3) or the 39007X(1-4).

Single Cylinder Gas Engine Test Stand. A 12 HP at 2,600 rpm engine runs from 900 to 4,500 rpm. MART = 291 lbf-in. The absorber LSF = 1. A DSF of 4 should be used due to high peak to average torque ratio and probability of a torsional resonance occurring. Thus, PPT = 291 X [4 + 1] = 1,455 lbf-in. The overload rating = > 2,910 lbf-in. Use an MCRT® 49703V(1-3); overload rating is 4,000 lbf-in, overrange is 1,500 lbf-in. With the filter at 200 hz and the output set to 10V at 1,000 lbf-in, data is instantaneous torque with 0.01% resolution. Set the filter to 1 Hz and set the 10V output to 300 lbf-in, data is average torque with 0.033% resolution.

Induction Motor Driven Fan. A 15 HP, 875 rpm, 3 phase motor drives a 25” fan. From equation 1, MART = 1,080 lbf-in. From page 2, the LSF = 1 and DSF = 0. Thus, PPT = 1,080 X [1 + 0] = 1,080 lbf-in; sensor overload = > 2,160 lbf-in. However, fan inertia is much greater than the motor’s. When starting across the line, the sensor sees the motor starting torque; 3 X MART or, 3,240 lbf-in. Thus, sensor overload rating = > 6,480 lbf-in, not 2,160 lbf-in. A flanged sensor handles thrust. Use either an MCRT® 39060X(2-3) or 49060V(2-3).

AC Motor Driven Centrifugal Water Pump. A 200 HP, variable frequency 3 phase drive runs the pump from 520 to 3,600 rpm. Using Equation 1 and 520 rpm, MART = 24,240 lbf-in. From page 2, LSF = 1 and DSF = 1; PPT = 24,240 X [1 + 1] = 48,480 lbf-in. Thus, the sensor overload rating = > 96,960 lbf-in. Foot mounting is preferred for large sensors at higher speeds. No significant extraneous loads exist. Select an MCRT®29007T(25-3) or 49007V(25-3). Both provide the needed immunity to EMI from the adjustable speed drive (ASD).

Belt Driven Mixer Assembly. The mixer is driven from 60 to 250 rpm. The dc, variable speed motor is rated ¾ HP. Belt tension is 350 pounds. From Equation 1, MART = 262 lbf-in at 60 rpm. From page 2, LSF = 2 and DSF = 0.5. Thus, PPT = 262 X [2 + 0.5] = 656 lbf-in. The sensor overload = > 1,313 lbf-in. The belt loads are too high for shaft or flanged torque sensors. An MCRT® 3120TA(5-2) pulley torquemeter handles 750 pound radial loads, and has the required measuring range and overload capacity (rated 2,500 lbf-in).

Diesel Engine Driven Generator. The 12 cylinder diesel is rated 1,080 HP at 1,800 rpm. From Equation 1, MART = 37,815 lbf-in. The variable load yields an LSF =2, DSF = 0.5; see page 2. Thus PPT = 37,815 X [2 + 0.5] = 94,537 lbf-in and overload capacity = > 189,075 lbf-in. No unusual extraneous load conditions exist. A flanged sensor is needed to save space. Select either an MCRT® 29070T(96-3), 29070T(48-3), 39070X(48-3) or 49070V(48-3) depending on desired output data format and accuracy requirements.