

Drives and Motor Sizing Made Easy

Drive and motor sizing made easy

- Size your drive and motor in three easy steps
 - Determine the application requirements
 - Size the motor to meet the application
 - Size the drive to meet the motor and the application

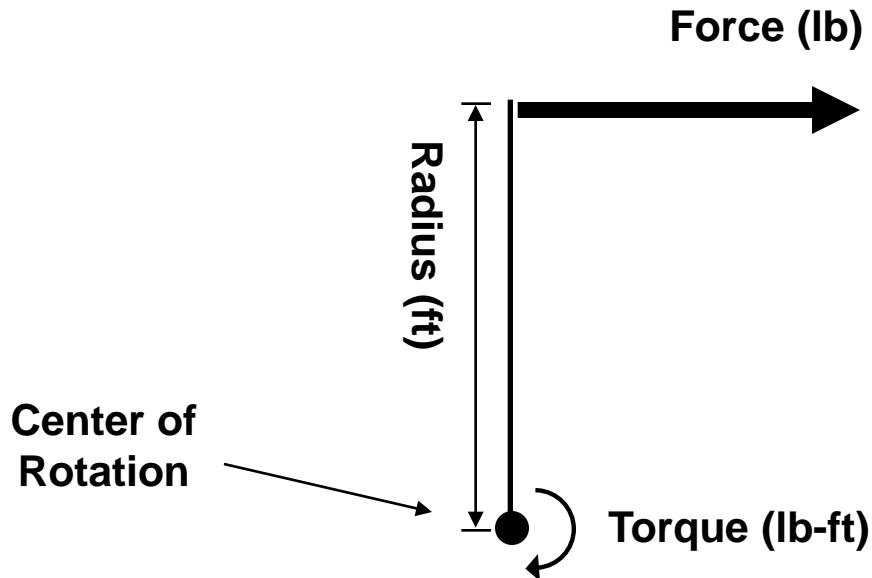


Determine the application requirements

- What are the torque requirements?
 - Motor torque (not power) is usually the decisive factor
 - Torque requirement establishes current requirement
 - Continuous torque requirements
 - Variable torque vs. Constant torque
 - Intermittent (peak) torque requirements
 - Starting torque
 - Acceleration torque
- What is the speed requirement?
 - Maximum speed
 - Minimum speed

Torque, what is it?

- A measure of the effect of a force applied at a distance to an axis
 - Torque is a force that tends to rotate or turn things
 - $\text{Torque (lb-ft)} = \text{Force (lb)} \times \text{Radius (ft)}$



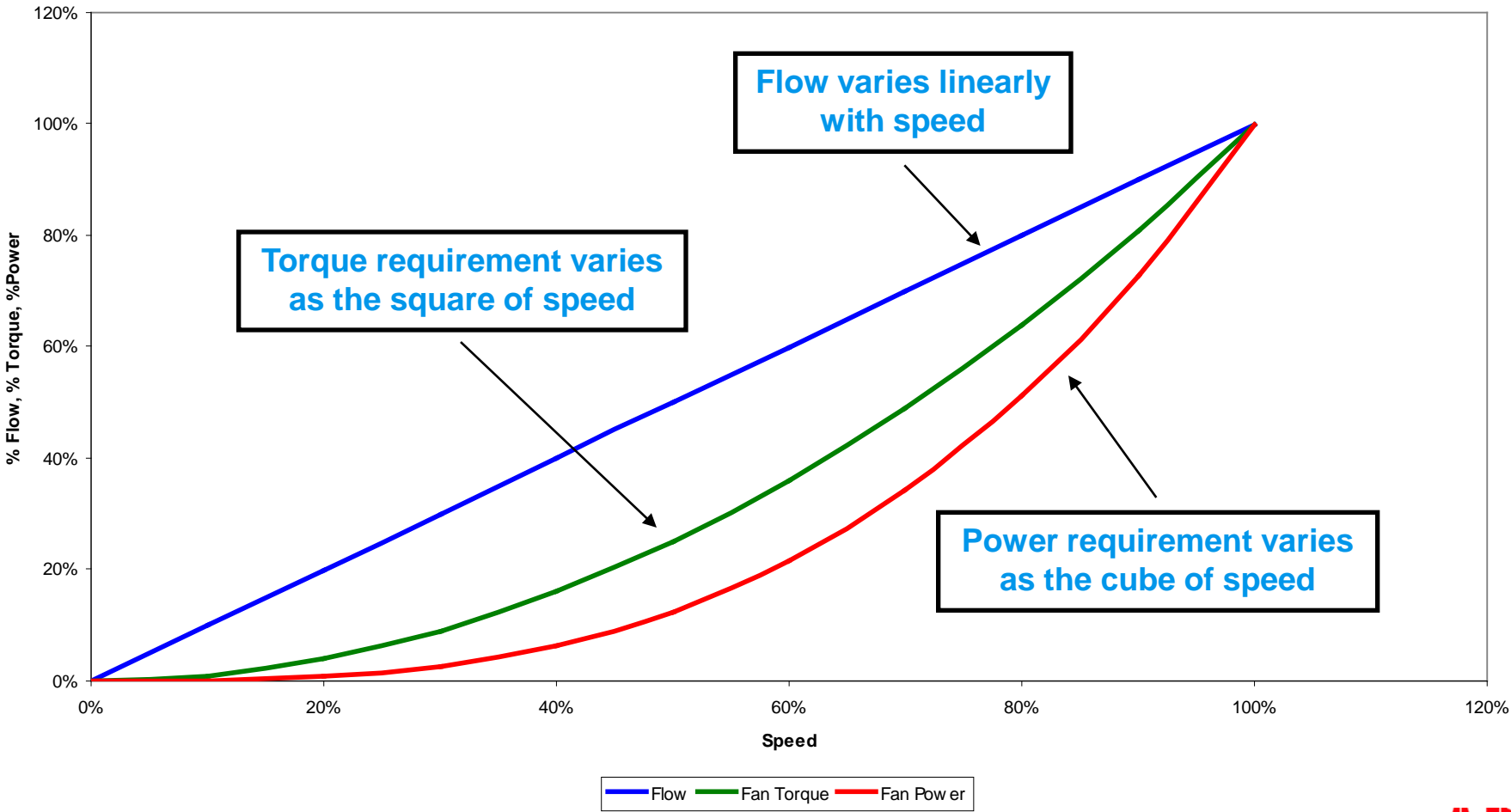
Variable Torque

- Variable torque changes as the operating speed changes
 - Fans
 - Centrifugal Pumps
 - Centrifugal Blowers
 - Mixers (material dependent)



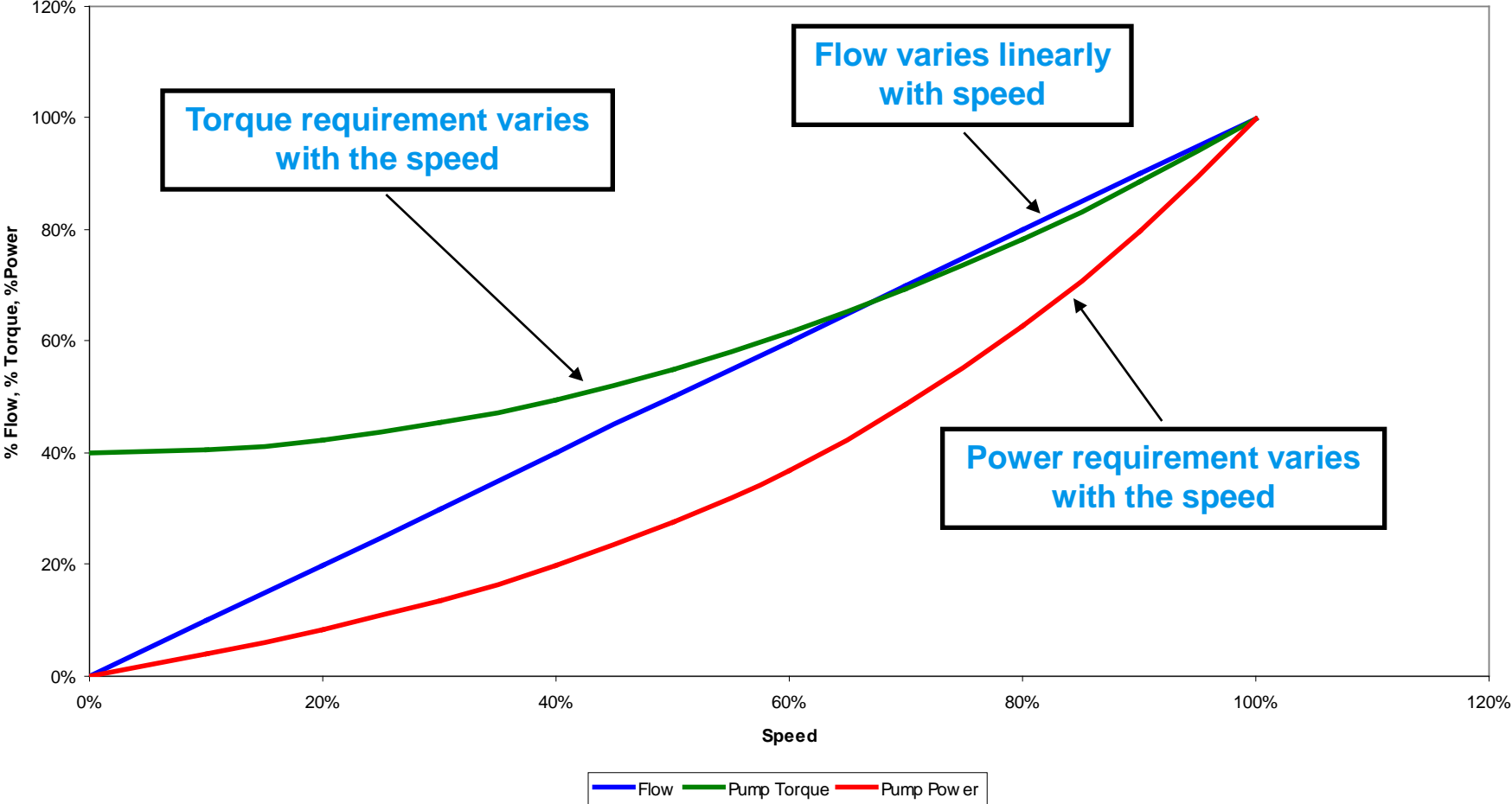
Variable Torque (fan with no static head)

Variable Torque



Variable Torque (pump with static head)

Variable Torque



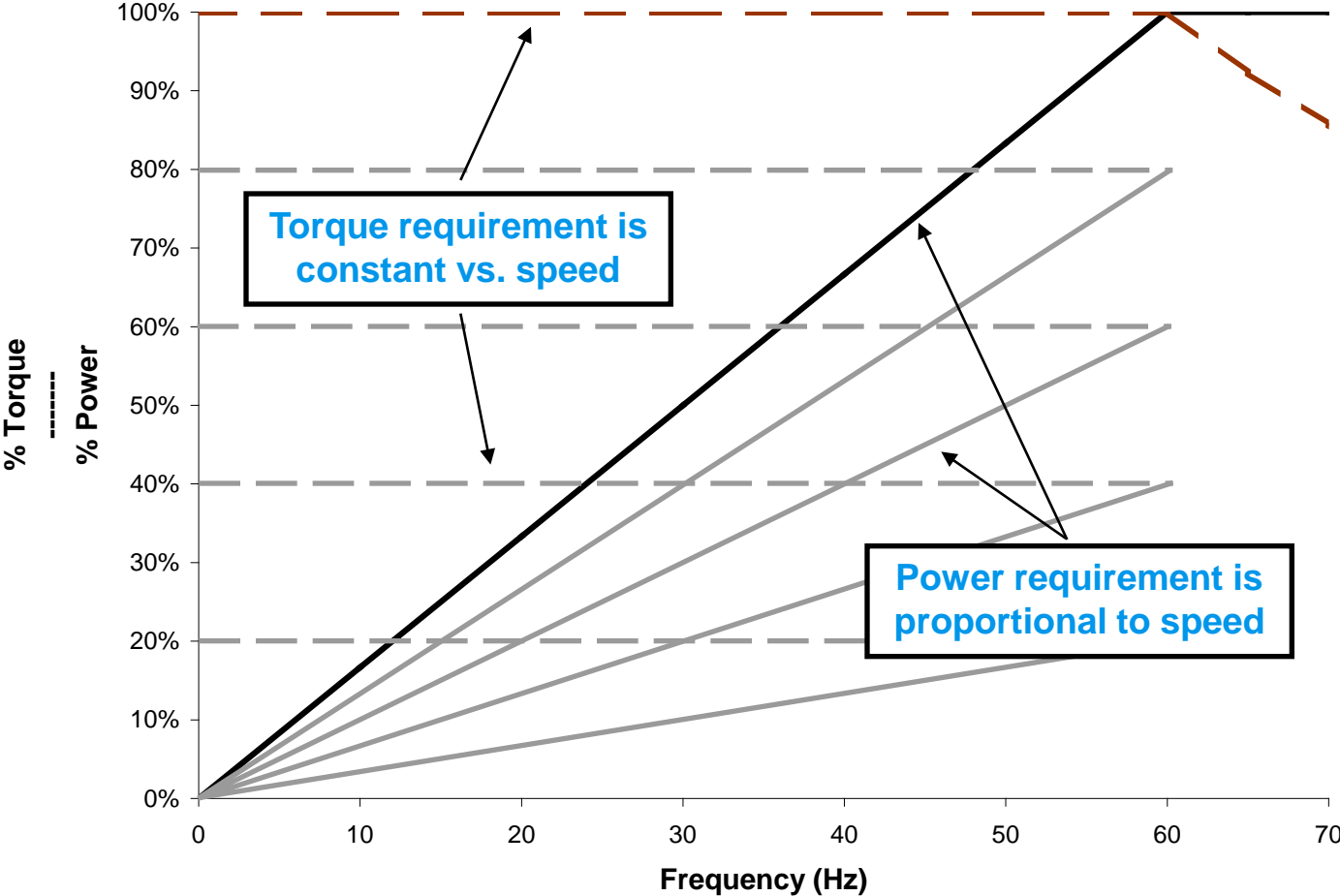
Constant Torque

- Constant torque remains the same as the speed changes
 - Conveyers
 - Positive Displacement Pumps
 - Extruders
 - Crushers
 - Mixers (material dependent)
 - Rotary Kilns
 - Hoists
 - Elevators



Constant Torque

Constant Torque

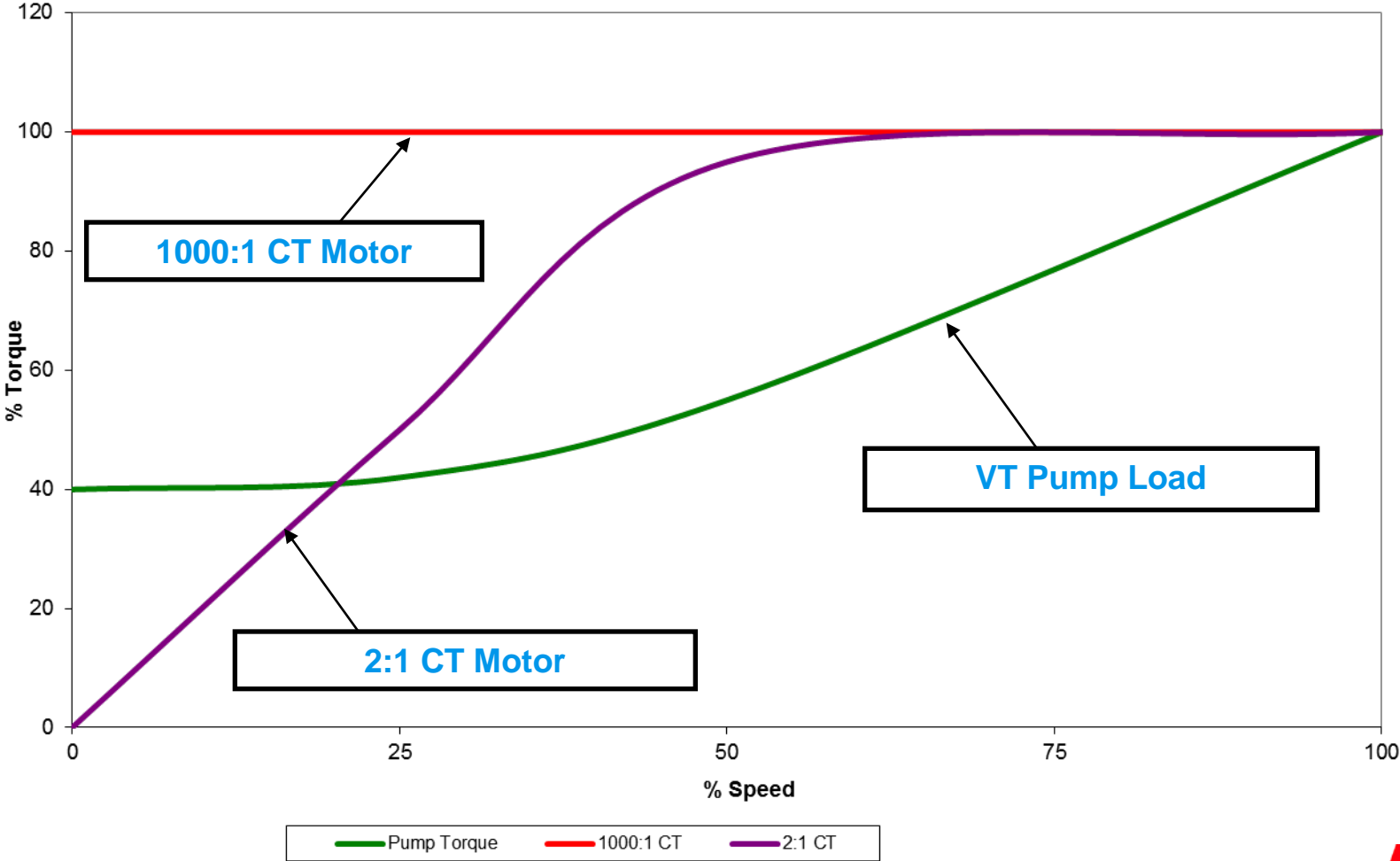


Constant Vs. Variable Torque

- Why should I care?
- Isn't all torque the same?
- Yes. But
 - Motor current is proportional to torque
 - Motor heating is proportional to current
 - In the case of a TEFC motor, cooling is proportional to speed
- Result --- **a TEFC motor's ability to thermally handle torque varies with speed**
- A **constant torque load often requires a larger TEFC motor** than that required for an equivalent variable torque load

TEFC Motor Torque

TEFC Motor

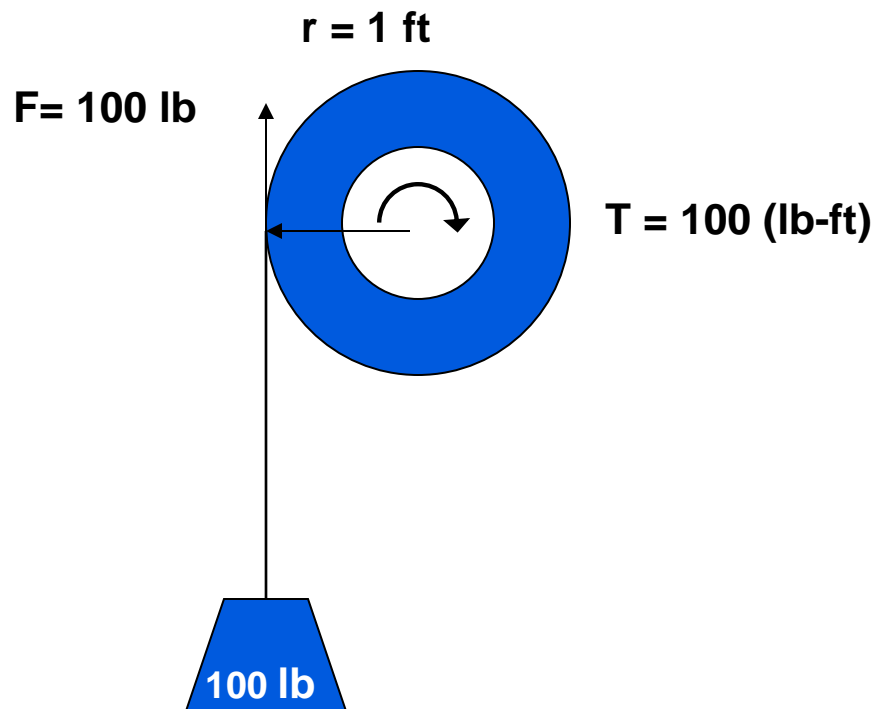


Intermittent torque

- Intermittent torque is torque that is required for a relatively short period of time. Examples:
 - Torque to breakaway the load and start motion
 - Friction
 - Torque to accelerate the load
 - Inertia

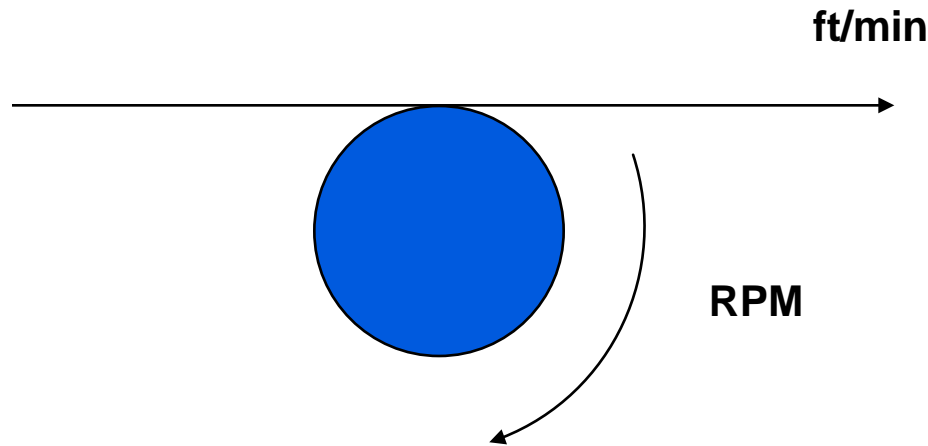
Torque Example

- Torque (lb-ft) = F (lb) x r (ft)



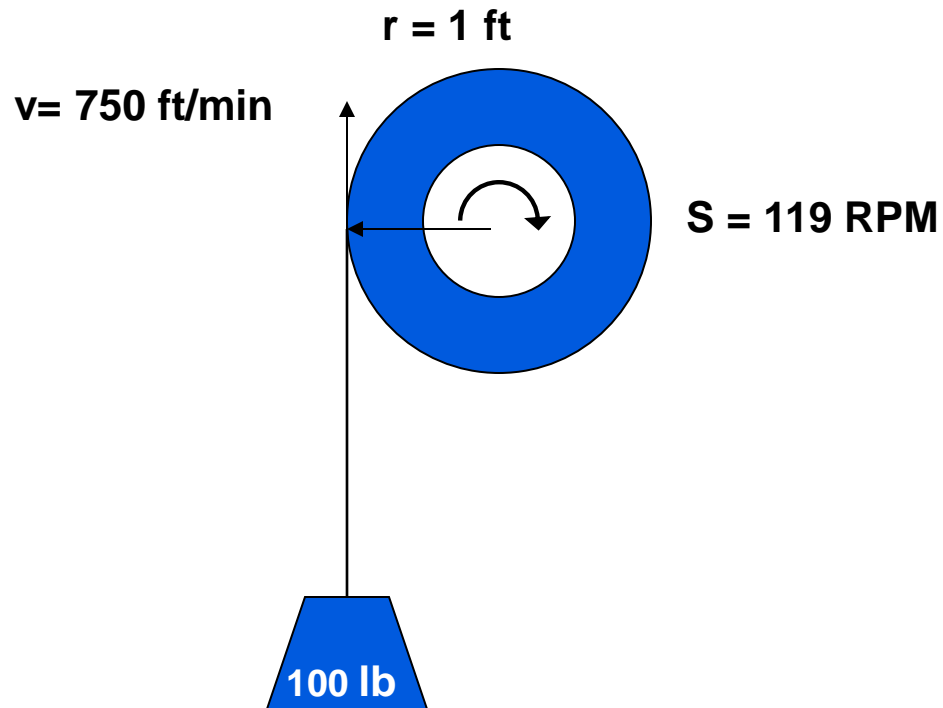
Speed

- With direct mechanical drive, motor speed is determined by mechanical speed and physical dimensions
- Speed (RPM) = v (ft/min) / (r (ft) x 2 x pi)



Speed Example

- Speed (RPM) = $v(\text{ft}/\text{min}) / (r(\text{ft}) \times 2 \times \pi)$
- Speed (RPM) = $750(\text{ft}/\text{min}) / (1 (\text{ft}) \times 2 \times \pi) = 119 (\text{RPM})$



Power

- Power is the product of torque times speed
 - Power (HP) = Torque (lb-ft) x Speed (RPM) / 5252
 - For our example:
 - Torque = 100 lb-ft
 - Speed = 119 RPM
 - Power = 100 (lb-ft) x 119 (RPM) / 5252 = 2.3 HP

Motor Sizing

- In our example
 - Torque = 100 lb-ft
 - Speed = 119 RPM
 - Power = $100 \times 119 / 5252 = 2.3$ HP
- What size motor do we pick?

A motor only develops its nameplate power at its nameplate speed. At a reduced speed it develops a proportionately reduced power.

| HP | Base Speed | Rated Torque |
|-----|------------|--------------|
| 3 | 1790 | 9 |
| 5 | 1790 | 15 |
| 7.5 | 1790 | 22 |
| 10 | 1790 | 29 |
| 15 | 1790 | 44 |
| 30 | 1790 | 88 |
| 40 | 1790 | 117 |

Motor Sizing

| HP | Base Speed | Rated Torque |
|-----|------------|--------------|
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| 15 | 1790 | 44 |
| 30 | 1790 | 88 |
| 40 | 1790 | 117 |

- What if we add a gear box?
 - Torque at motor = torque / gear ratio
 - Speed at motor = speed x gear ratio
- Now what motor do we pick?

| Gear Ratio | 1 | 2 | 5 | 10 | 15 |
|-------------------------|-----|-----|-----|------|------|
| Torque at motor (lb-ft) | 100 | 50 | 20 | 10 | 6.7 |
| Speed at motor (RPM) | 119 | 239 | 597 | 1194 | 1790 |

Intermittent torque

- Torque for Acceleration
 - Torque = Inertia x Acceleration Rate
 - If you know:
 - Inertia (WK^2) in lb-ft²
 - Acceleration Time in sec.
 - Change in motor speed in RPM
 - Then:
 - Torque = WK^2 (lb-ft²) x Speed(RPM) / (Accel Time(sec.) x 307.6)

Intermittent torque

- Torque for Acceleration
 - Assume for our example:
 - Total $WK^2 = 1.2 \text{ lb-ft}^2$
 - Includes 100 lb load, drum, 15:1 gear box and motor
 - Change in speed is 1790 RPM
 - If accel time is 10 seconds
 - Accel Torque = $1.2(\text{lb-ft}^2) \times 1790(\text{RPM}) / (10(\text{sec.}) \times 307.6)$
 - Accel Torque = 0.7(lb-ft)
 - Total torque = $6.7 + 0.7 = 7.4 \text{ lb-ft}$; less than rated motor torque
 - If accel time = 1 second
 - Accel Torque = $1.2(\text{lb-ft}^2) \times 1790(\text{RPM}) / (1(\text{sec.}) \times 307.6)$
 - Accel Torque = 7.0 (lb-ft)
 - Total torque = $6.7 + 7.0 = 13.7 \text{ lb-ft}$, 150% of rated motor torque

Pick a drive

- Assume for our example:
 - Motor is 3 HP, 1790 rpm, 4.2 FLA, 9 lb-ft
 - Torque to lift load and accel in 10 s is 7.4 lb-ft
 - Max Current is less than 4.2 amps
 - Use 3 HP normal duty drive, 4.9 amps, with 110% O.L. (5.4 amps peak)
 - Torque to lift load and accel in 1 s is 13.7 lb-ft
 - Max current is about 6.4 amps
 - Use 3 HP heavy duty drive, 5.6 amps, with 150% O.L. (8.4 amps peak)

Sample Rating Table

| ACS800-U1 size | I_{max} A | Normal use | | Heavy-duty use | | Frame size | Air flow ft ³ /min | Heat dissipation BTU/Hr |
|--|----------------|---------------|-------------|----------------|----------------|------------|----------------------------------|----------------------------|
| | | I_{2N} A | P_N HP | I_{2hd} A | P_{hd} HP | | | |
| Three-phase supply voltage 208 V, 220 V, 230 V or 240 V | | | | | | | | |
| -0002-2 | 8.2 | 6.6 | 1.5 | 4.6 | 1 | R2 | 21 | 350 |
| -0003-2 | 10.8 | 8.1 | 2 | 6.6 | 1.5 | R2 | 21 | 350 |
| -0004-2 | 13.8 | 11 | 3 | 7.5 | 2 | R2 | 21 | 410 |
| -0006-2 | 24 | 21 | 5 | 13 | 3 | R3 | 41 | 550 |
| -0009-2 | 32 | 27 | 7.5 | 17 | 5 | R3 | 41 | 680 |
| -0011-2 | 46 | 34 | 10 | 25 | 7.5 | R3 | 41 | 850 |
| -0016-2 | 62 | 42 | 15 | 31 | 10 | R4 | 61 | 1150 |
| -0020-2 | 72 | 54 | 20 * | 42 | 15 ** | R4 | 61 | 1490 |
| -0025-2 | 86 | 69 | 25 | 54 | 20 ** | R5 | 147 | 1790 |
| -0030-2 | 112 | 80 | 30 | 68 | 25 ** | R5 | 147 | 2090 |
| -0040-2 | 138 | 104 | 40 * | 80 | 30 ** | R5 | 147 | 2770 |
| -0050-2 | 164 | 132 | 50 | 104 | 40 | R6 | 238 | 3370 |
| -0060-2 | 202 | 157 | 60 | 130 | 50 ** | R6 | 238 | 4050 |
| -0070-2 | 282 | 192 | 75 | 154 | 60 ** | R6 | 238 | 4910 |
| Three-phase supply voltage 380 V, 400 V, 415 V, 440 V, 460 V or 480 V | | | | | | | | |
| -0004-5 | 6.5 | 4.9 | 3 | 3.4 | 2 | R2 | 21 | 410 |
| -0005-5 | 8.2 | 6.2 | 3 | 4.2 | 2 | R2 | 21 | 480 |
| -0006-5 | 10.8 | 8.1 | 5 | 5.6 | 3 | R2 | 21 | 550 |
| -0009-5 | 13.8 | 11 | 7.5 | 8.1 | 5 | R2 | 21 | 690 |
| -0011-5 | 17.6 | 14 | 10 | 11 | 7.5 | R2 | 21 | 860 |
| -0016-5 | 24 | 21 | 15 | 15 | 10 | R3 | 41 | 1150 |
| -0020-5 | 32 | 27 | 20 | 21 | 15 | R3 | 41 | 1490 |
| -0025-5 | 46 | 34 | 25 | 27 | 20 | R3 | 41 | 1790 |

Special cases

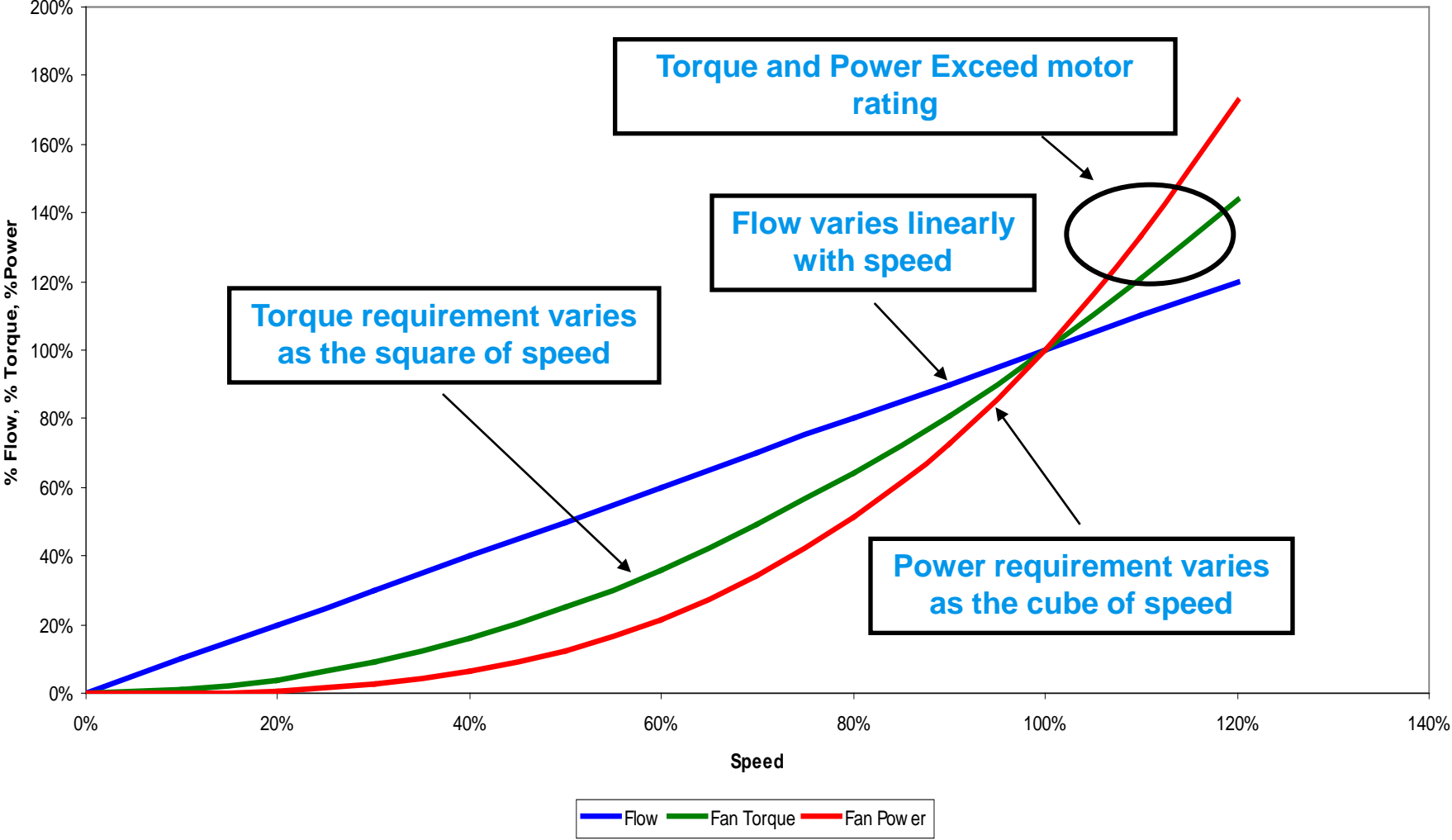
- Intermittent torque is required for a relatively long time
 - Large inertias
 - Results in long accel time, several minutes
 - Drive and motor sized for acceleration torque
 - Examples
 - Centrifuges
 - Kilns
 - Long periods of breakaway torque
 - Mixer starting with product

Watch the limits

- Limits that can come in to play
 - Torque
 - AC Motors have max torque limits, about 200% (Drive limits motor to about 70% of motor's rated breakdown torque)
 - Speed
 - Limited by maximum safe mechanical speed
 - Limited by maximum drive frequency
 - Limited by reduced maximum torque above base speed (Constant HP operation)
 - Current
 - Limited by inverter
 - Full speed motor current rises when line voltage is low
 - Regenerative (Braking) Torque
 - If less than 10% Flux braking may be good enough
 - If more than 10% but intermittent, such as stopping only, use brake chopper and resistor
 - If more than 10% and continuous, consider a regenerative drive

Variable Torque Above Base Speed

Variable Torque



Conclusion

- Drive sizing made easy
 - Determine the application's requirements
 - Torque
 - Continuous
 - Intermittent
 - Speed
 - Pick the motor
 - Try to gear in to run at base speed
 - Size on torque not power!
 - Pick the Inverter
 - Continuous current
 - Overload current

Now, that's easy!

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