Guidance - Turndown Ratio

The turndown ratio is the ratio of the maximum capacity of a device or system to the minimum capacity, which usually means the minimum controllable capacity or measurement sensitivity.

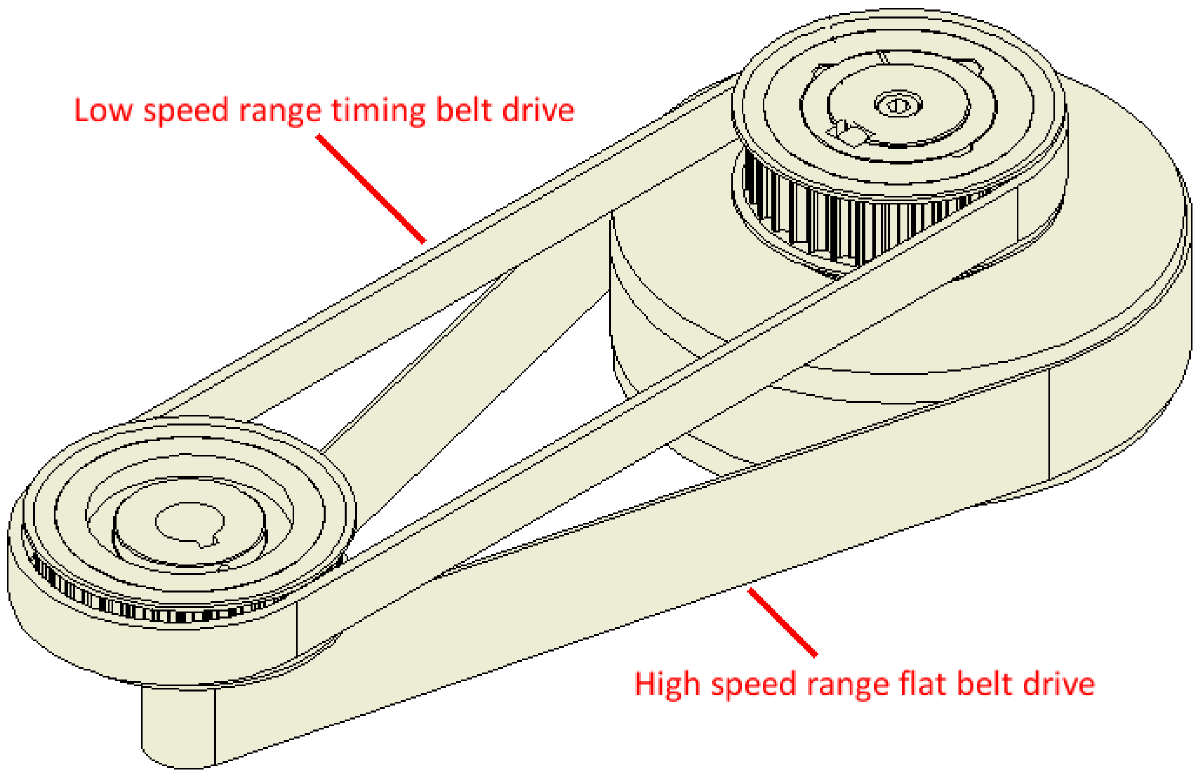
For example:

Test Load: 1 N to 2000 N would represent a turndown ratio of 2000:1.

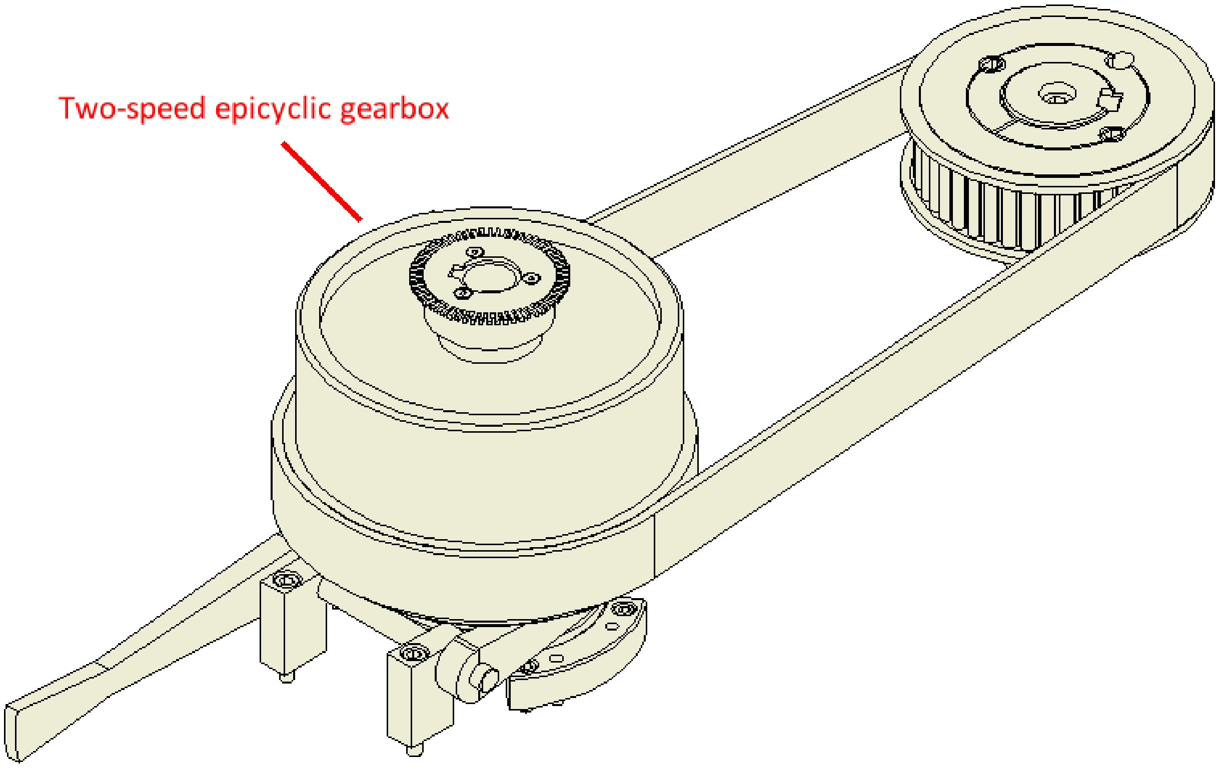
Speed Range: 1 to 10000 rpm would represent a turndown ratio of 10000:1.

Most real engineering systems achieve a turndown ratio of, at best, 100:1, with common devices, frequently much less, for example, for a car internal combustion engine, the turndown ratio is something like 7.5:1, in other words, 6000 rpm divided by 800 rpm, which is probably the minimum speed at which the engine will run!

With a car, we improve the overall turndown ratio by including a multi-ratio gearbox. With a test rig, we can do the same with interchangeable drive belts:



Or with multi-speed gearboxes:



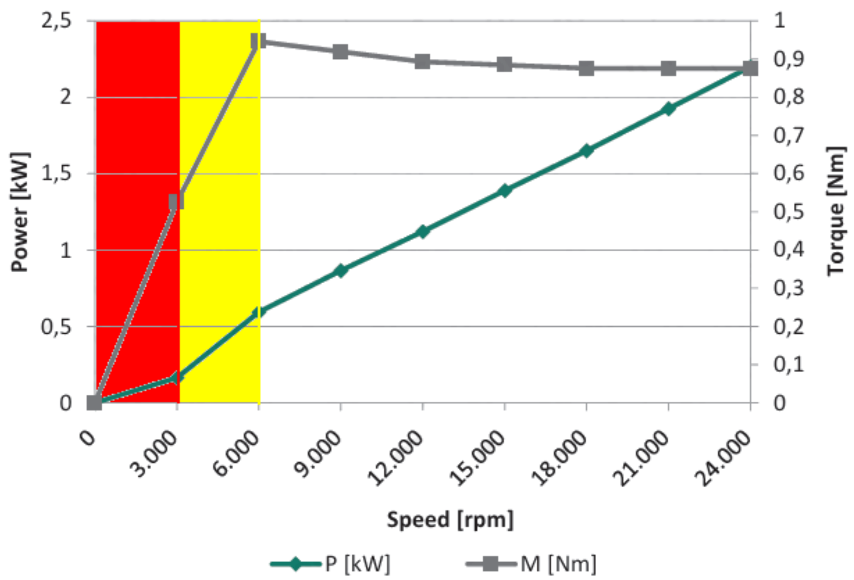
It is important, when considering the turndown ratio of a motor or drive, to consider the motor characteristic. The controllable speed range of a motor depends on the type of motor, the type of control and the load.

The turndown ratio for the motor is the ratio of minimum speed relative to the base speed and is typically the minimum speed at which the motor can be operated, without suffering thermal damage.

Most force ventilated a.c. vector motors, with encoder feedback, will safely achieve a turndown ratio of 50:1, which means a four-pole motor, which has a base speed of 1500 rpm at 50 Hz excitation, should run satisfactorily at 30 rpm, or less. However, a suitable high-performance motor and drive, may provide satisfactory operation at frequencies up to 200 Hz, giving speeds up to four times base speed, hence 6000 rpm. The overall controllable speed range is thus 30 rpm to 6000 rpm, so the resulting turndown ratio, based on maximum speed, becomes 200:1.

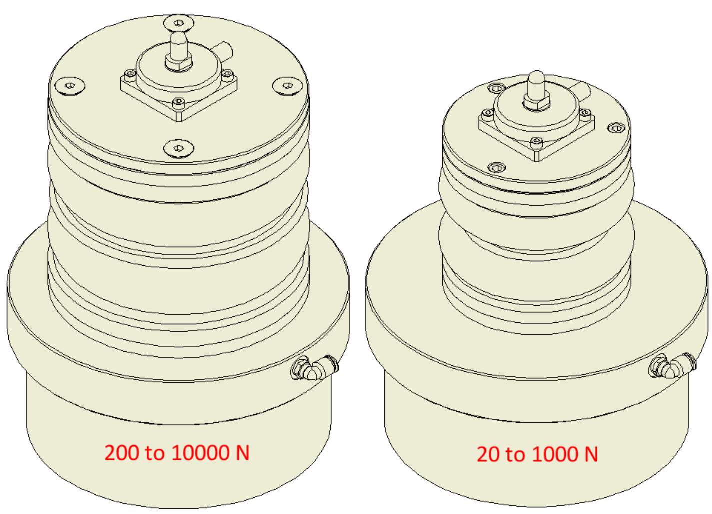
Due consideration must be given to load factor, which, if small, may mean that the motor can be run at very low speeds, nominally extending the turndown ratio. However, if the load factor is large, the turndown ratio will decrease. In essence, except perhaps with brushed d.c. servo motors, most motors generate very little torque at zero speed.

An example of this is direct drive, using a very high-speed a.c. spindle motor. Whereas the motor may have a maximum speed of, say, 24000 rpm, and controllable speeds down to hundreds of rpm, the torque-speed characteristic of the motor means that it will not run smoothly, or not run at all, against a load, at low speeds; the motor may stall. There will be corresponding no-load and full-load turndown ratios.



In an application using a spindle motor such as that illustrated, the solution is to start a test with zero or minimal applied load, and only increase the test load to that required once the motor is running at sufficient speed to generate the necessary torque. So, the motor speed range might be, say, 300 to 24000 rpm, but the usable test speed range, may sensibly only be 3000 to 24000 rpm.

When it comes to loading systems, we reliably achieve a turndown ratio of 50:1 with servo controlled pneumatic bellows, with force transducer feedback.



By using interchangeable bellows, the resulting “system” turndown ratio can be increased to 10000:20, hence 500:1. Changing bellows assemblies is doing the same for load in the same way as changing pulley ratios extends the speed range.

When it comes to sensors such as force transducers, the turndown ratio (or rangeability) of the measurement system is defined differently from the previous examples. The ratio is calculated by dividing the maximum input that the device can measure, in other words, the upper range limit, by the minimum calibrated span, which is the minimum input that can be measured accurately. Hence for a 1000 N transducer that can sensibly be calibrated over a 100 N range, the turndown ratio, as defined here, would be 10:1.

To calculate an equivalent to the earlier definition of turndown ratio, we would need to know the minimum force that can be reliably measured at the most sensitive calibrated range. If, for example, we were able to detect 1 N force reliably, with our 1000 N transducer calibrated over a 100 N range, we could state that the overall turndown ratio, following a calibrated range change, was 1000:1. If, on the other hand, a measurement deadband, zero offset, or non-linearity, means that we can only measure down to 2 N, with the necessary degree of precision and repeatability, then the turndown ratio, with calibrated range change, would be 500:1.

For many devices, such as force transducers, pressure sensors and flow meters, we need to know the measurement threshold, in order to make a meaningful assessment of turndown ratio.