ALLOWABLE DUTY CYCLE WHEN OPERATING BRUSHLESS MOTORS IN THEIR INTERMITTENT CURRENT RANGE

There have long been “rules of thumb” in the brushless servo motor industry about what is acceptable to use as a duty cycle when operating in the “peak” or “intermittent” range. There have also been “rules of thumb” applied to how long any given motor can operate at peak current on an instantaneous basis.

Many times you will here reference to numbers like 1 second or half a second as acceptable times to operate in the peak range, and it is believed that if you are in peak for one second, and then off for one second, you’ll have an acceptable duty cycle, in this case, 50%.

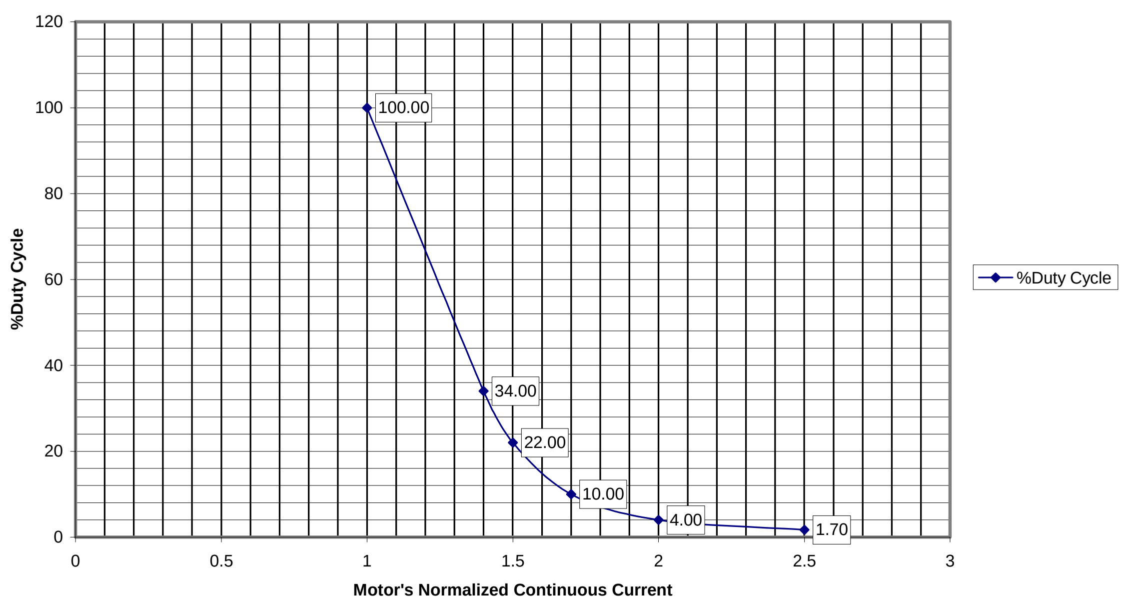
That is very far from the truth. Exlar has conducted extensive thermal testing of many brushless motors, our own and others, and, the following is true for virtually any brushless servo motor.

When the motion profile of a brushless servo motor requires that it enter the “peak” or intermittent range during every cycle, the duty cycle is limited, somewhat exponentially, as the percentage peak current increases.

Below is the duty cycle curve for operating in the “peak” or intermittent range of a brushless motor. The current is "Normalized" such that 100% duty cycle corresponds to "1" being the motor's maximum continuous current for a 130°C winding with a 25°C ambient and the example motor, and Exlar SLM 115, was attached to a 12"x12"x1/2" heat sink. Hence "2" on this curve corresponds to twice the continuous rated current.

In this curve you will see that if operating at an 2X continuous current, the acceptable duty cycle is 4%. So, if you are at 2X continuous current for 1 second, you will need to be without power to the motor for 24 seconds to achieve the acceptable duty cycle of 4%.

<u>%Duty Cycle vs Motor's Normalized Continuous Current</u>
(%Duty Cycle = Time "on"/(Time"on" + Time"off")
Motor Attached to 12"x12"x1/2" Aluminum Heat Sink,
Maximum Winding Temp = 130°C, Ambient = 25°C



Another item to consider is that depending upon the motor's thermal time constant, powering the motor "on" with 2X current for 10-minutes and then turning it "off" for 240 minutes corresponds to 4% duty cycle. However a smaller (60mm or 90mm frame) motor will "overheat" in less than 10-minutes with 2X rated current. Hence, this curve is only a "guideline" and can not be applied blindly!

When considering how long a motor can be operated in the peak range, the starting temperature must also be accounted for. The maximum allowable time “on” is going to be the time in which the motor’s stator reaches 130°C. This time is obviously longer if the starting temperature is 25°C than if it is 55°C. The cool down time must then allow for cooling back to the original starting temperature.

Another critical factor to consider is that using a motor’s case temperature as a gauge of allowable duty cycle is only acceptable when operating beneath the continuous rated current of the motor.

This is because the thermal time constant of the wire in the motor’s stator is far shorter than the thermal time constant of the motor’s case. The wire in the stator will heat many times faster when subjected to currents in the “peak” or intermittent range, than will the case.

For example, at 2X rated current, one tested motor’s stator increased from 25°C to 130°C in 90 seconds. In that same 90 seconds, the motor case had increased only 10°C. Also, due to the interrelationship between the components of the motor with different thermal time constants, and the flow of thermal energy in the motor, the motor’s case will continue to rise in temperature when the power is removed from the motor in this example.

The thermal time constant of the wire in the stator is also less than that of temperature sensors and switches that are integrated into the stators. Therefore, when subjected to high peak currents, it is possible for the stator to be demagnetized, or the stator failed before the thermal switch or sensor has indicated that the motor is in an overheated condition.