MAGNET-SCHULTZ OF AMERICA
SPECIALISTS IN ELECTROMAGNETIC DEVICES

CASE STUDY INVOLVING PULSE WIDTH MODULATION (PWM)

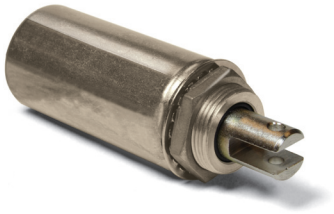
Objective

Demonstrate the effect of powering a Pulse Duty Solenoid with Power Control Module, utilizing PWM circuitry by comparing:

1) *The performance of a Pulse Duty solenoid, when energized by a conventional powering scheme (at constant voltage), with the performance of the same solenoid when powered by PWM circuitry.*

2) *For contrast, the performance of a Continuous Duty solenoid, of the same size, powered by conventional powering scheme (at constant voltage) is also presented.*

SOLENOID PLATFORM



A cylindrical, pull style solenoid, 1" dia. x 2" long was used for testing
Two different coil designs were compared:

- A PULSE DUTY COIL: coil resistance 6 ohms, and
- A CONTINUOUS DUTY COIL: coil resistance 105 ohms

TEST METHOD

Each solenoid was mounted, vertically, onto Zwick Force vs. Stroke Test equipment, with the plunger pointing up and connected to a load cell. The solenoid's plunger was extended to 1" stroke. Power was then applied to the solenoid coils as described below. Relevant Force/Stroke, Heat Rise and Duty Cycle data was then plotted on Charts 1, 2 and 3 respectively.

TEST 1: Continuous Duty Solenoid, PICK & HOLD Force Test, Conventional Driving Scheme, (the blue curves on Charts 1 & 2)
A constant voltage (24 VDC) was applied to the coil.

TEST 2: Pulse Duty Solenoid, PICK FORCE Test, Conventional Driving Scheme, (the green curves on Charts 1 & 2)
A constant voltage (24 VDC) was applied to the coil for 10 seconds. Care was taken not to overheat the coil.

TEST 3: Pulse Duty Solenoid, PICK FORCE Test, PWM Driving Scheme, (the purple curves on Chart 1)
A Power Control Module, utilizing PWM circuitry to drive the solenoid, was adjusted for 100 duty cycle, on time 100ms @ 24VDC

TEST 4: Pulse Duty Solenoid, HOLD FORCE Test, PWM driving Scheme, (the red curves on Charts 1 & 2)
A Power Control Module, utilizing PWM circuitry to drive the solenoid, was adjusted for optimal HOLD performance 25.5 % duty cycle @ an effective voltage of 6.2 VDC.
This was done so as to correlate the heat rise characteristics of the Pulse Duty solenoid with the Continuous Duty solenoid.

TEST RESULTS

TEST 1: The resulting Force vs. Stroke curve can be seen in Chart 1, depicted by the blue line.

The resulting Heat Rise curve can be seen in Chart 2, depicted by the blue line.

TEST 2: The resulting Force vs. Stroke curve can be seen in Chart 1, depicted by the green line.

The resulting Heat Rise curve can be seen in Chart 1, depicted by the green line.

TEST 3: The resulting Force vs. Stroke curve can be seen in Chart 1, depicted by the purple line.

TEST 4: The resulting Force vs. Stroke curve can be seen in Chart 1, depicted by the red line.

The resulting Heat Rise curve can be seen in Chart 2, depicted by the red line.

CHART 1: **FORCE vs. STROKE**

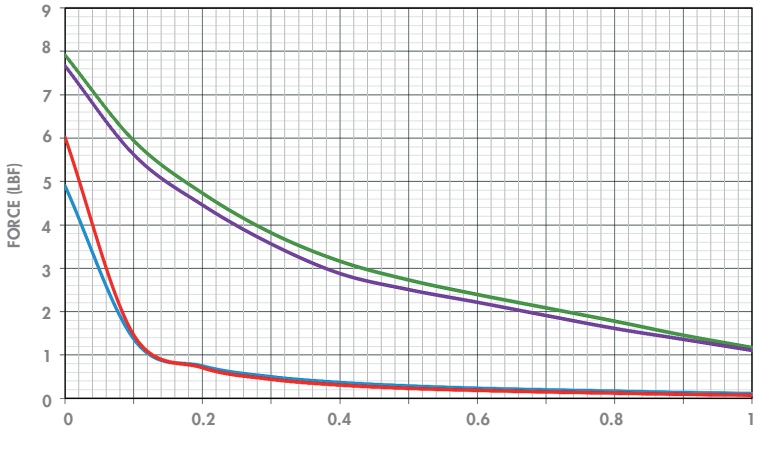
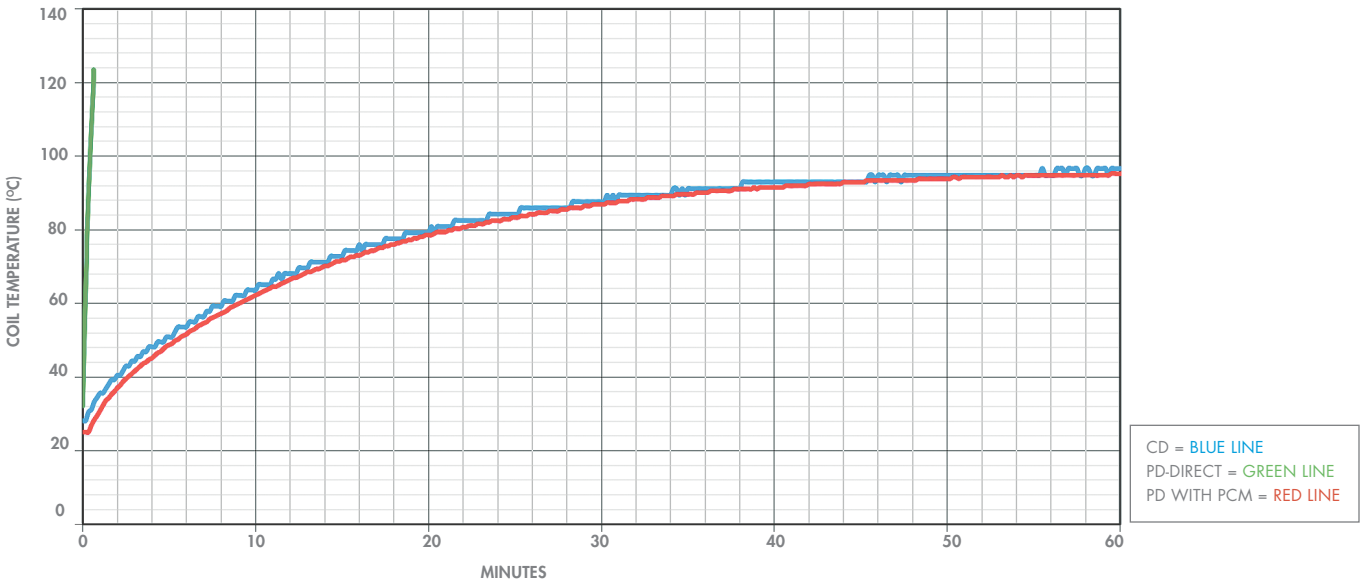


CHART 2: **HEAT RISE**



Conclusions

FORCE vs. STROKE COMPARISONS

PICK Force: The Pulse Duty Coil's Force/Stroke curve, when utilizing the PWM Power scheme, is within 6% of the Pulse Duty Coil's Force/Stroke curve utilizing the conventional power scheme. This difference is due to the inherent losses within the Power Control Module's circuitry.

NOTE: The higher current level, and the 100ms On-time for the PICK cycle in Chart 3.

HOLD Force: The Pulse Duty Coil's Force/Stroke curve, when utilizing the Power Control Module, is nearly identical to the Continuous Duty Coil's Force/Stroke curve utilizing the conventional power scheme. Only below .1" stroke is there a noticeable difference, which is attributed to the manufacturing tolerances between the two solenoids.

The significance of these characteristics demonstrate that PWM enables one to achieve a significantly higher PICK Force of the Pulse Duty solenoid, yet still operate in a Continuous Duty fashion.

NOTE: The extended (continuous) On-time, and the much lower current level for the HOLD cycle in Chart 3.

TEMPERATURE vs. TIME COMPARISONS

The Pulse Duty Coil Temp/Time curve, when utilizing the PWM Power scheme, is nearly identical to the Continuous Duty Coil Temp/Time curve utilizing the conventional power scheme.

All of this information, coupled with the depiction of current levels and On-time in Chart 3, demonstrates that the PWM power scheme enables the short duration of a high PICK current to be combined with a continuous, but much lower HOLD current, thereby allowing a Pulse Duty solenoid to remain energized without overheating.

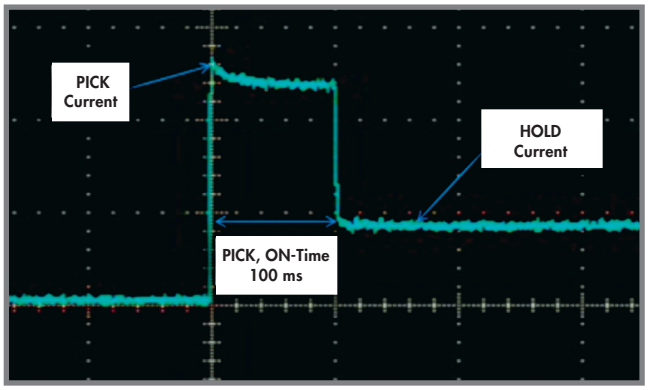


CHART 3: **PWM GENERATED, PICK & HOLD CURRENTS**

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