R&D Results – The Development of a High Accuracy Multipole Strip Magnet for Non-Contact Linear and Rotary Position Measurement

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Market Need

In global industry there is a need for the accurate, repeatable and reliable measurement of linear and rotary motion and position. This includes needs in the fields of aerospace, oil and gas exploration and production, semiconductor manufacturing, automotive, military, medical and other industries. Applications include monitoring the movement of linear shafts and pistons, rotating gears and wheels, pivoting joints, and basically the motion of any one mechanical component in a piece of equipment relative to another. Applications can be as small as miniaturized focus modules for biometric ID, to the motions controls for a CNC gantry type coordinate measuring machine.

There are many options available to measure linear and rotary motion including contact systems such as potentiometers and mechanical proximity switches, and non-contact systems utilizing optical/laser, magnetostrictive, capacitive, inductive, ultrasonic, and other principals. Of these, the non-contact options offer many benefits; long life and high reliability due to limited component wear and degradation, limits damage that may occur from contact with a work piece, allows for the encapsulation or potting of the component pieces of the measuring system to protect them from the environment, and others.   These measuring systems can offer a high degree of system accuracy, but are also often accompanied by a relatively high price to achieve these benefits. There is a market need for a non-contact system that can measure linear and rotary motion with a high degree of accuracy, and provide the system components to accomplish this at a lower cost.

Hall cell technology offers such an option. The Hall-Effect principal was discovered by physicist Edwin Hall in 1879 (Figure 1). He discovered that when an electrical conductor or semiconductor with current flowing through it in one direction was subjected to a magnetic field perpendicular to the direction of the current flow, a voltage could be measured across the conductor at a right angle to the current path.

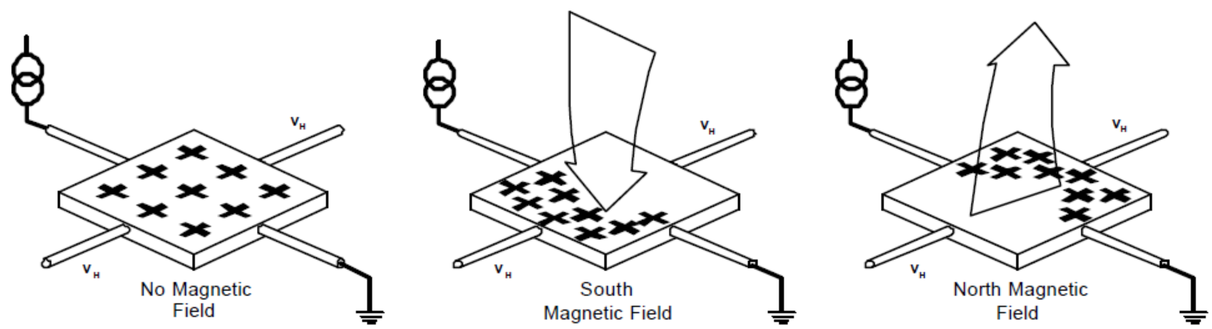
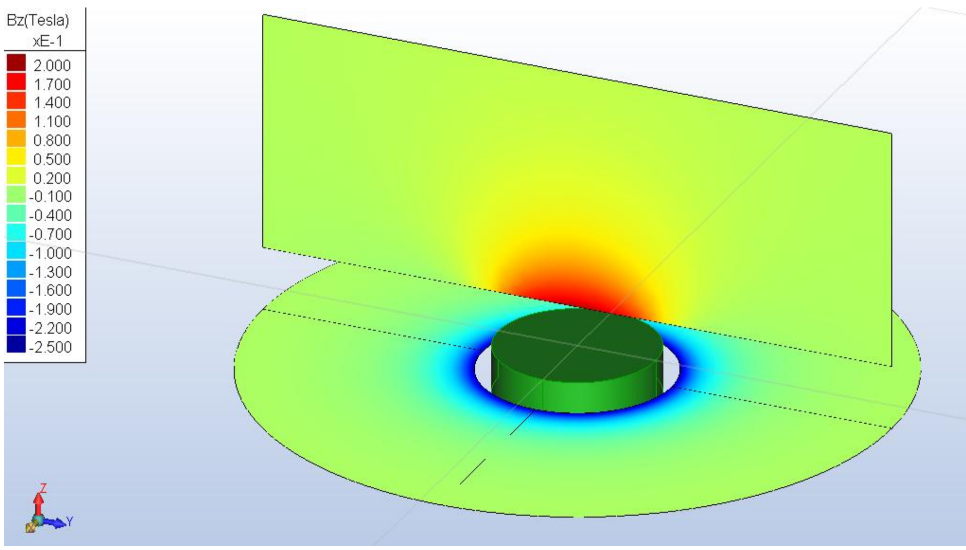


Figure 1

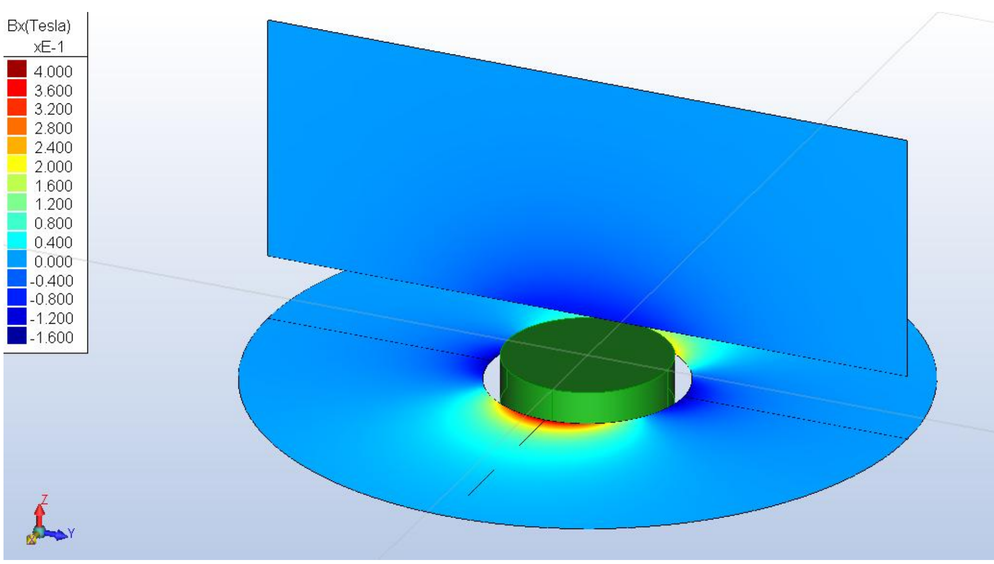
This induced voltage has three key characteristics. First, its strength is proportional to the strength of the current in the conductor and to the strength of the magnetic field passing through the conductor. Second, the change in the induced voltage with changes in the current and magnetic field strength is repeatable. Lastly, this phenomenon is measurable. This basic principle can be applied to the development of a low cost non-contact sensor to measure linear and rotary motion. In use, to measure the movement of one location, surface or component relative to another, a Hall sensor is attached to one location and a magnet is attached to the other. As the two location change position relative to each other (either linear or rotary) this change in position can be directly measured by the change in the induced voltage across the Hall sensor, in a completely non-contact environment.

One of the limitations of measuring linear position with Hall sensors is the limited range and accuracy of measurement due to limitations in the magnetic field of a “traditional” bipole axially or diametrically magnetized magnet, with a single North and South Pole. The strength of the magnetic field of this size bipole magnet drops below the required minimum for the AMS multipole Hall sensors within 15 to 20 millimeters from the surface of the magnet, depending upon the specific magnet used. To increase linear measurement distance and accuracy when using a Hall sensor a magnet with multiple North/South poles, with very precise pole lengths, is needed.

Magnetic Field of an Axially Oriented Magnet

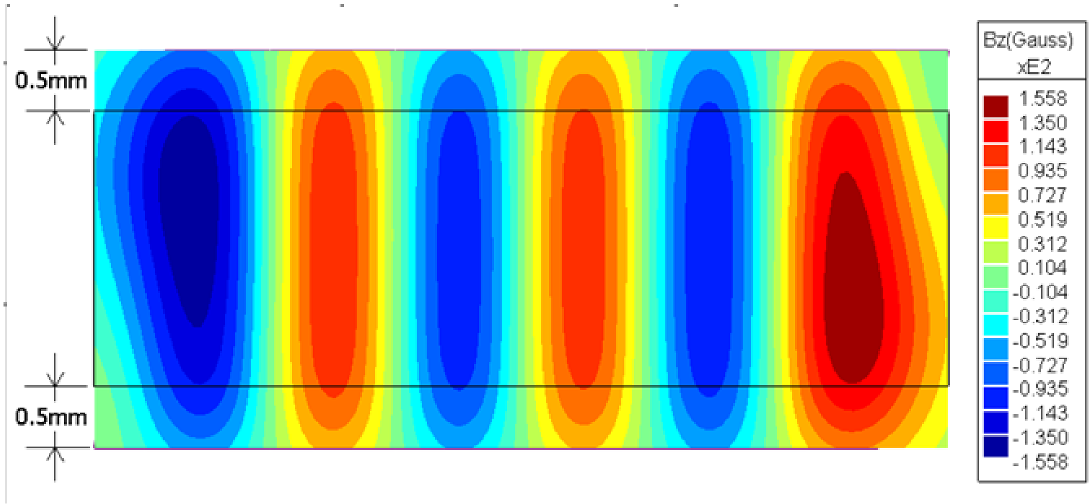


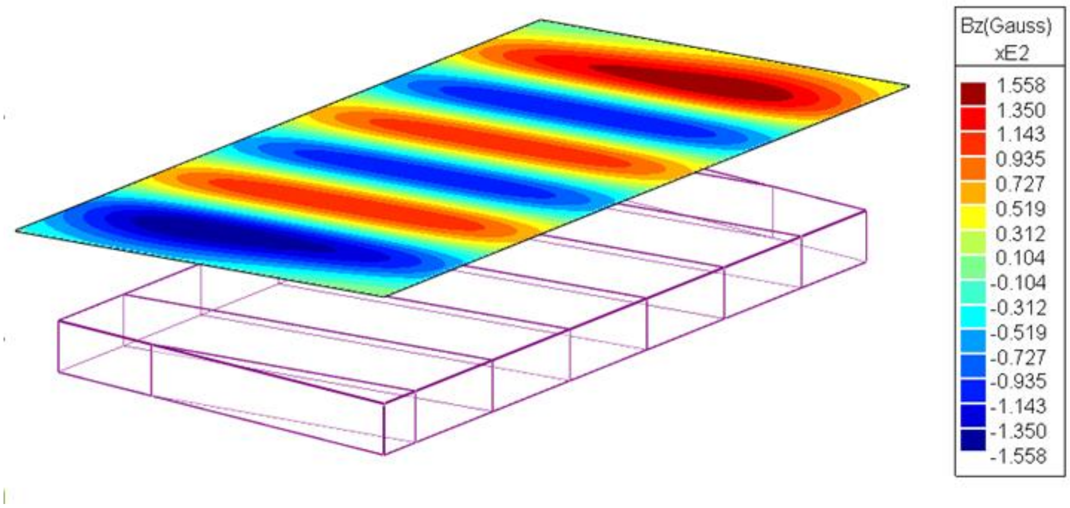
Magnetic Field of a Diametrically Oriented Magnet



A multipole magnet will offer the required field strength in a continuous pattern of repeating North and South poles. The length of linear measurement capable with a multipole magnet is limited only by the length of magnet that can be physically made.

Magnetic Field of a Multipole Strip Magnet





Development Issues

The development of high accuracy, low cost, linear and rotary position measurement systems will require the development of Hall sensors that utilize multipole magnets, and the development of the multipole magnets themselves. Austriamicrosystems (AMS) has developed a family of non-contact high resolution magnetic encoders for accurate linear and off-axis rotary sensing. These sensors offer a measurement resolution of down to <0.5 micron. A multipole strip magnet or ring magnet with a pole length of 1.0mm, 1.2mm, or 2.0mm, depending upon sensor, is required for the sensor to operate properly. There are several requirements of these magnets for an overall measurement system to be successful. The magnets must be made of a material that can be magnetized to sufficient field strength to meet the requirements of the Hall sensors. They must also be made of a material that can produce magnets in numerous different lengths as required by the end-user, and must be easily cut to achieve these different length. And perhaps most importantly, the magnetizing process must result in a highly accurate and repeatable pole length.

Development Results

Dexter Magnetic Technologies has developed a multipole strip magnet with a pole length of 1.0 mm, 1.2mm, or 2.0mm, with a pole length accuracy within 2.0% of a pole pair (40 um for a 1.0 mm pole length) (Figure 2). Different materials were investigated to produce the magnets with a final selection made of a flexible ferrite material with an Energy Grade of 1.4 MGOe that exhibits the required characteristics for proper magnetizing and cutting to length while offering a low cost. Two standard sizes were developed and tested. One is 1.5mm thick by 9.5mm wide; the other is 0.76mm thick by 3.18mm wide. The magnets can be magnetized to produce a 10 mT field at 1.0mm, meeting the AMS sensor requirement of a magnetic field strength range at the surface of the sensor of 5 mT to 60 mT. The magnet has an operating temperature range of -40° to 80° C and a Linear Coefficient of Thermal Expansion of 5×10^{-5} ° C^{-1} (Figure 5). The magnets can be produced with a pressure sensitive adhesive applied to the non-magnetized side to allow mounting of the magnet on a range of surface material and textures. A 3M Double Coated Paper Tape 410M was selected as having the required properties for a wide range of applications. The use of a flexible ferrite material to produce the magnets allows for the production of very long magnets, up to 5,000mm or longer.

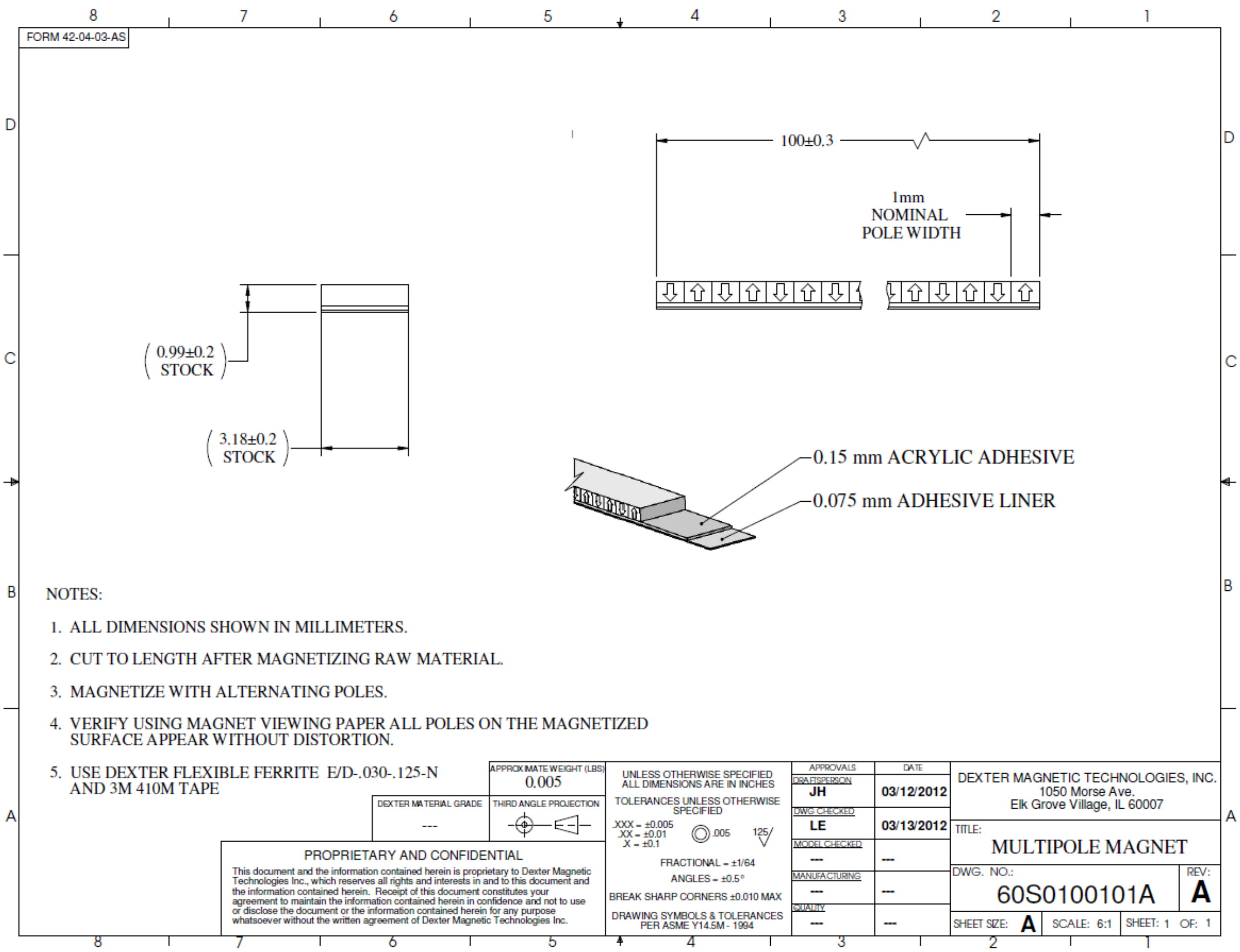


Figure 2

During development of the multipole magnet it became apparent that to test and measure the targeted accuracy of better than 40 microns a high accuracy, purpose designed test fixture was needed. To accomplish this a custom test fixture was designed and fabricated (Figure 3) initially for the 1.0mm pole length magnet design.

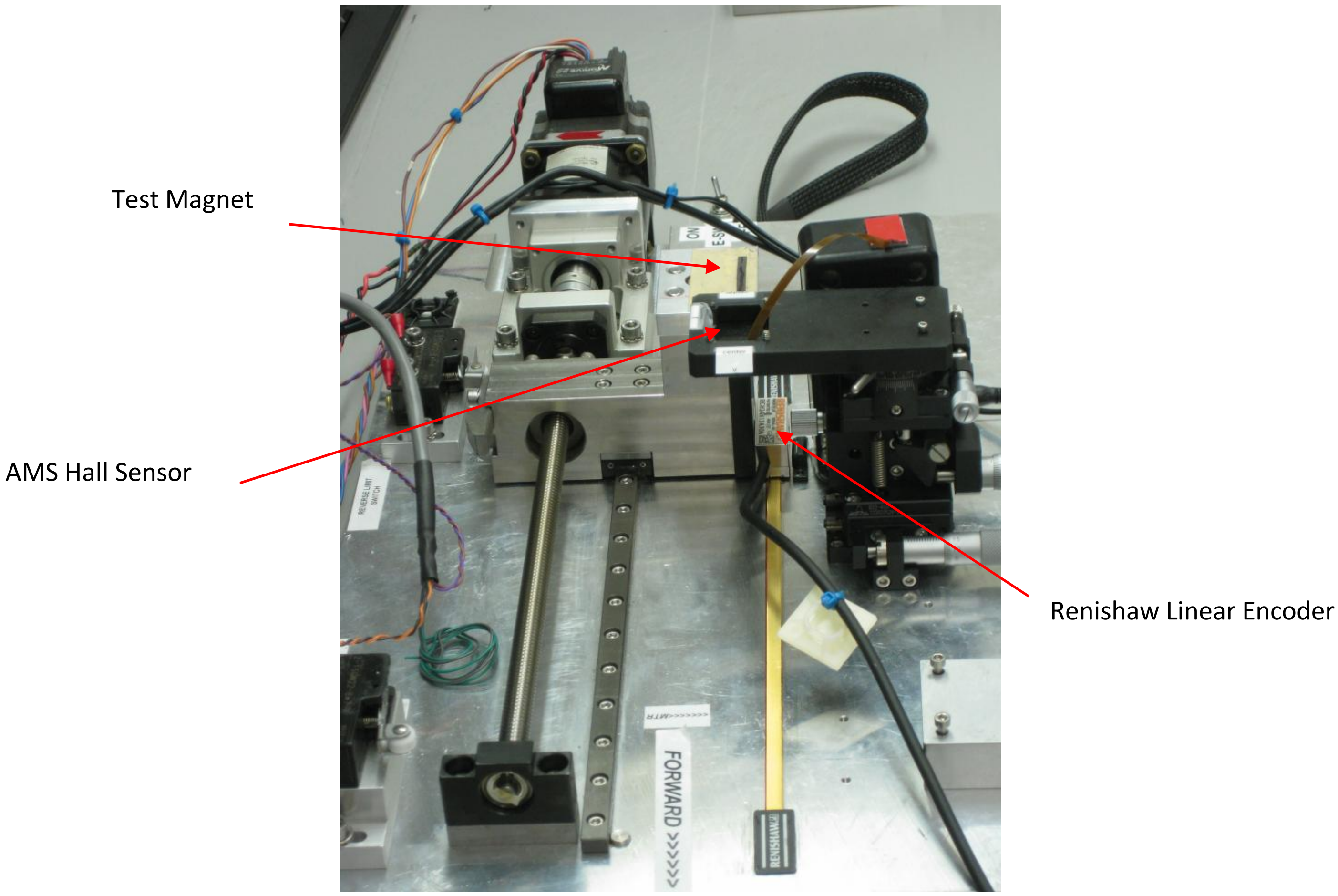


Figure 3

The magnet to be tested is mounted on a small sample platform, 0.5mm below a Hall sensor, which is attached to a carriage that is moved linearly by means of a stepper motor. To measure the linear movement of the magnet along the test fixture during testing a Renishaw optical encoder is used. This includes an RGS20-S linear scale with 20 micron graduations that is attach to the base of the testing fixture. An RGH24 readhead which provides 50 nanometer resolution is used to precisely measure movement of the test platform and the magnet being tested along the linear scale. An AMS NSE5310 Hall sensor is used to measure the magnetic field of the test magnet and its linear position as the sample platform moves along the testing fixture. The NSE5310 is a high resolution magnetic linear encoder that provides instant indication of the magnet position with a resolution of 0.488 microns per step (12 bit (4096) over a 2.0mm pole pair).

Testing of the multipole magnet indicated that magnetic end effects and the physical distortion of the magnetic material from cutting the magnet to length disturbed the magnetic profile of the first few pole pairs. After the first few pole pairs the magnet demonstrated a pole length accuracy within 2.0% of a pole pair (40 micron for 1.0mm pole) (Figure 4).

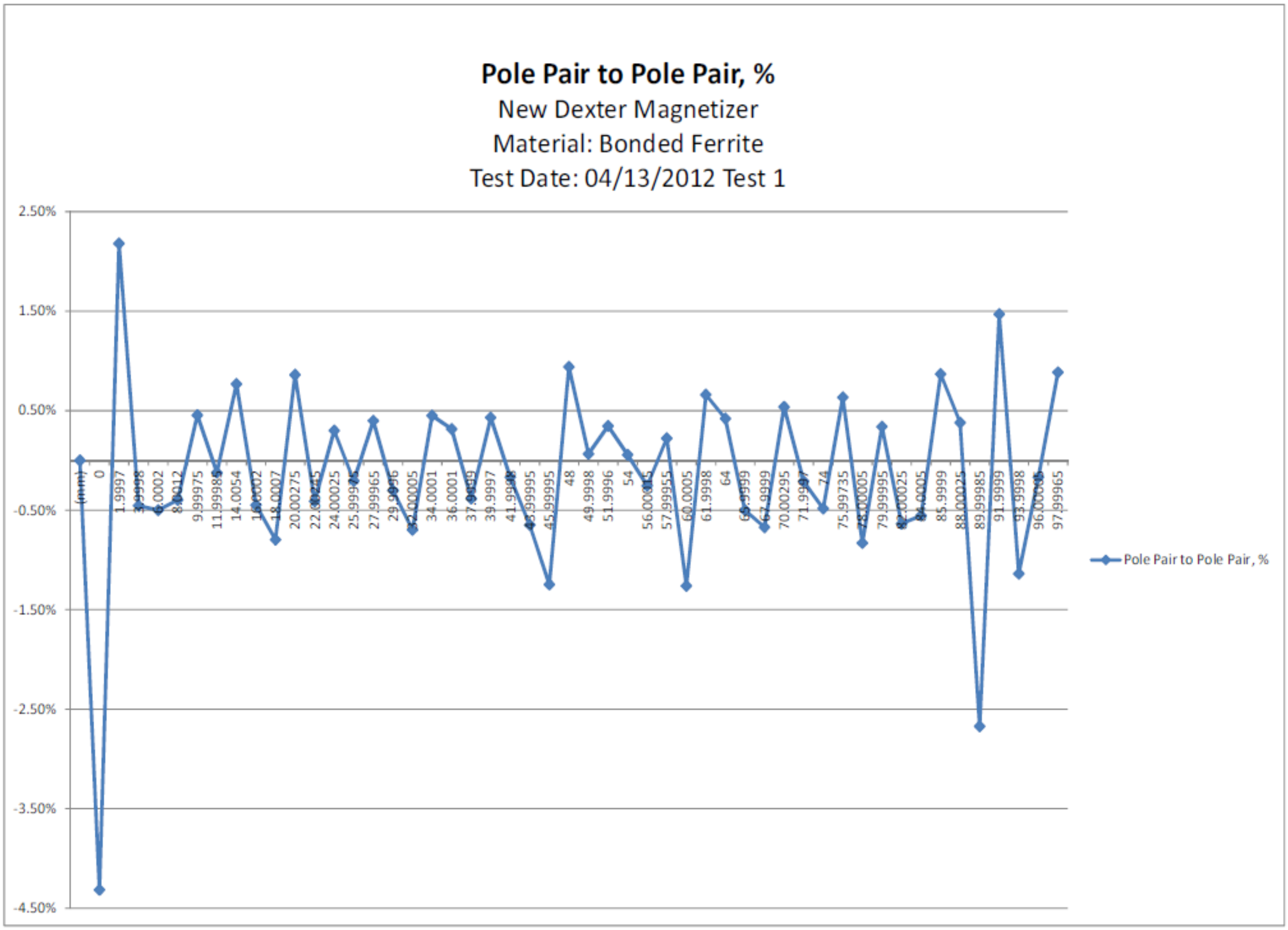


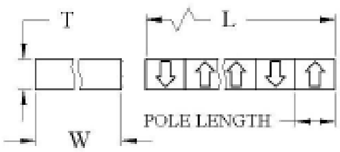
Figure 4

Next Steps

The testing fixture will be refitted with the AMS AS5306 and the AS5304 Hall cell linear magnetic encoder to allow testing of the 1.2mm pole length and the 2.0mm pole length multipole magnets.

Multipole Magnets for Encoders

- Our multipole magnets for encoders come with industry standard pole lengths, thicknesses and widths.
- Accuracy within 2.0% (40 µm) of measured position. Cumulative pole accuracy within 1% per 10 mm.
- Please use the alphanumeric coding system shown below to specify your multipole magnetic strip.



To configure, please select your specification from one of each box found below.

60S XXXX XX X X

Backing		
None	Adhesive	Steel

Strip Type	
1	2

Pole Length		
(10) 1.0mm	(12) 1.2mm	(20) 2.0mm

Strip Length (+/- 0.3mm)		
0100mm	0300mm	Custom lengths available upon request.

Strip Type	1	2
Physical Data		
Thickness (T)	0.76 +/- .15mm	1.5 +/- .15mm
Width (W)	3.18 +/- .5mm	9.5 +/- .5mm
Density	3.7 gram/cc	3.7 gram/cc
Durometer	50-70 Shore-D	50-70 Shore-D
Mass	~8.9 gram/m	~53 gram/m
Operating Temperature	-40° to 80°C	-40° to 80°C
Linear Coefficient of Thermal Expansion (CTE)	$5x10^{-5}$ °C^{-1}	$5x10^{-5}$ °C^{-1}
Magnetic Characteristics		
Material	Flexible Magnet	Flexible Magnet
Energy Grade	1.4 MGOe	1.4 MGOe
Temperature Coefficient of Magnetic Field Strength	-0.2%°C^{-1}	-0.2%°C^{-1}
Max. Operating Temp.	80°C	80°C

AMS Encoder Compatibility		
1.0mm	1.2mm	2.0mm
AS5311 NSE-5310	AS5306	AS5304

Figure 5