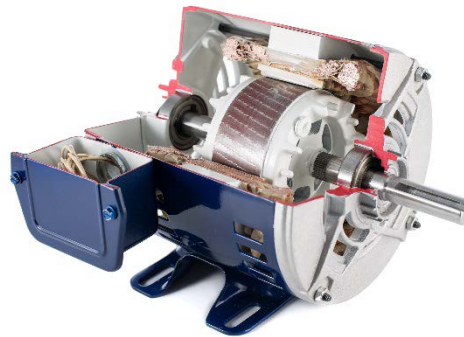


Motor Rewind With Zeus PEEK Insulation Products



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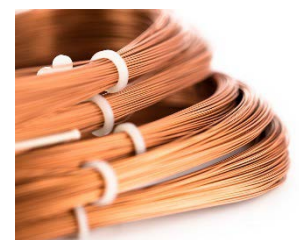


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ABSTRACT

The purpose of this case study was to capture the observations on materials and processing during the rewind of a motor using Zeus crystalline PEEK-coated magnet wire and Zeus PEEK Lay-Flat® tubing as insulating material. This study was done to compare the Zeus manufactured products to standard magnet wire and Nomex®, Nomex® laminate, and Dacron®-Mylar®-Dacron® (DMD) insulation materials. The Zeus PEEK magnet wire and PEEK Lay-Flat® insulating material displayed slightly increased stiffness and rigidity compared to the non-Zeus products. The more rigid

PEEK magnet wire provided greater resistance to coil motion in start-up, surge, and similar scenarios. The PEEK Lay-Flat® material exhibited greater resistance to tear and retained its shape when installed as slot insulation including cuff formation. While the Zeus-manufactured products initially required a familiarization period, manufacturing personnel were quickly able to adapt their usual installation techniques to the Zeus materials and easily complete the installation process with no added limitations. (See the corresponding Test Report describing how the Zeus-manufactured products improved motor performance in multiple areas).



PEEK Insulated Wire: The ideal solution for coil winding and magnet wire.

MOTOR

The motor selected for the model rewind was a new small 0.75 horsepower, 4-pole, 460 volt, Class F AC motor (**Fig. 1**). This motor was chosen because of its physically small size and light-weight dimensions for ease of transport to trade shows. Additionally, the motor style is one which is commonly available in the marketplace. Specifically for the motor, the short stator provided a means to evaluate the ease by which the PEEK magnet wire and slot insulation could be formed and installed into the motor. The narrow stator slots would

provide a means to evaluate the ease of inserting the magnet wire bundles into the stator slots. This test and design also included the use of phase paper.

The design of the motor had 36 slots. The motor used distributed winding which lead to a more complex winding diagram. The large coil had 120 turns in each winding, whereas the small coil had 64 turns. In addition, the lead wire on the rewind motor was PEEK insulated using crystalline 18 American wire gauge (AWG; 19 × 30 AWG SPC) with 10.6 mils insulation. This new insulation replaced the original motor EXAR® 18 AWG lead wire (Champlain Cable Corporation).

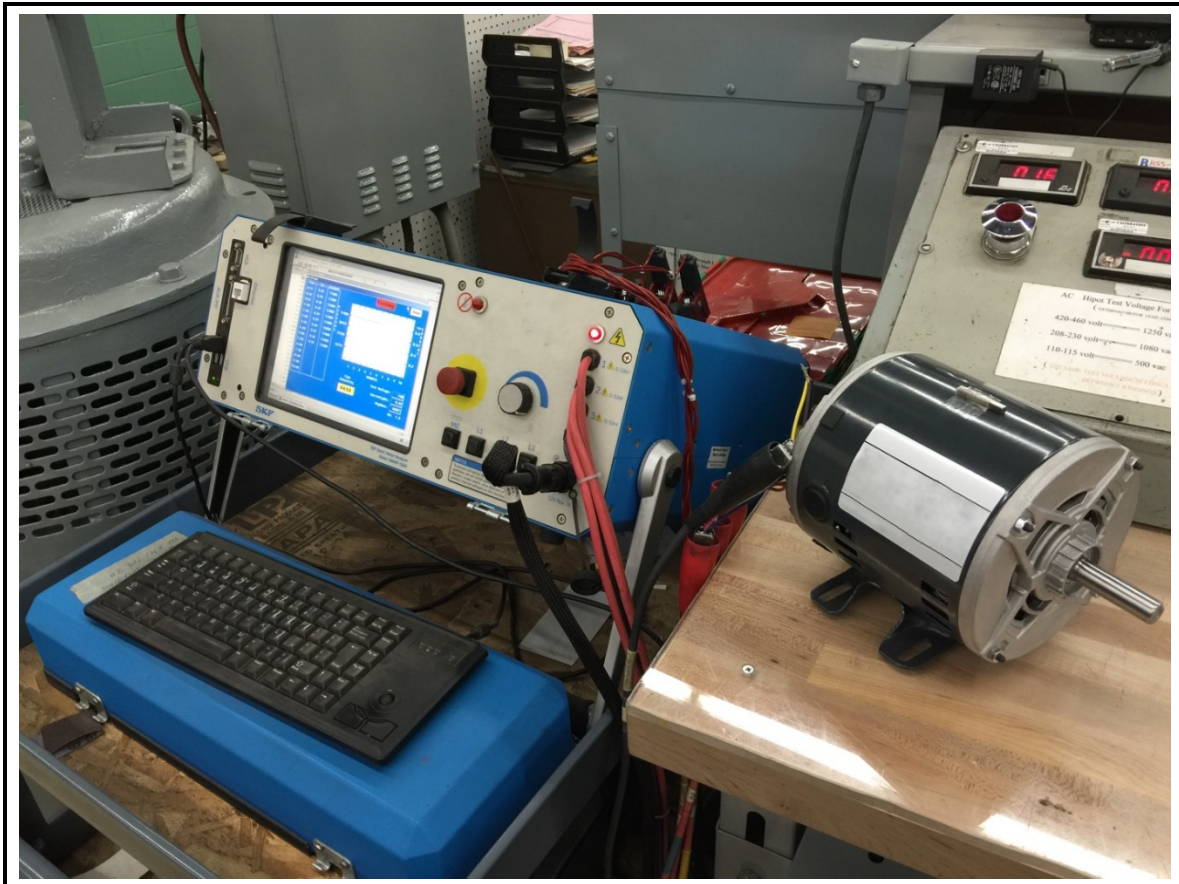


Figure 1: Original motor and test equipment prior to motor rebuild.

MAGNET WIRE

The original wire in the motor was 24 AWG standard enameled magnet wire 35, and this was replaced with Zeus crystalline PEEK magnet wire sized 24 AWG,

heavy build (1.1 mils). The operators found that the new wire was stiffer than standard magnet wire. The winding process, however, was not affected by this increased stiffness, and spooling was carried out as normal using an automated spooling machine.

Installation of the PEEK magnet wire winding into the slot was somewhat more difficult than installing the standard wire because the PEEK wire did not retain a bend as readily as standard wire (**Fig. 2**). This property of the PEEK wire was discussed with the operator.

Following a few additional slot insertions and some simple modifications to his assembly style, the operator was able to complete installation of the PEEK magnet wire with no further concerns.

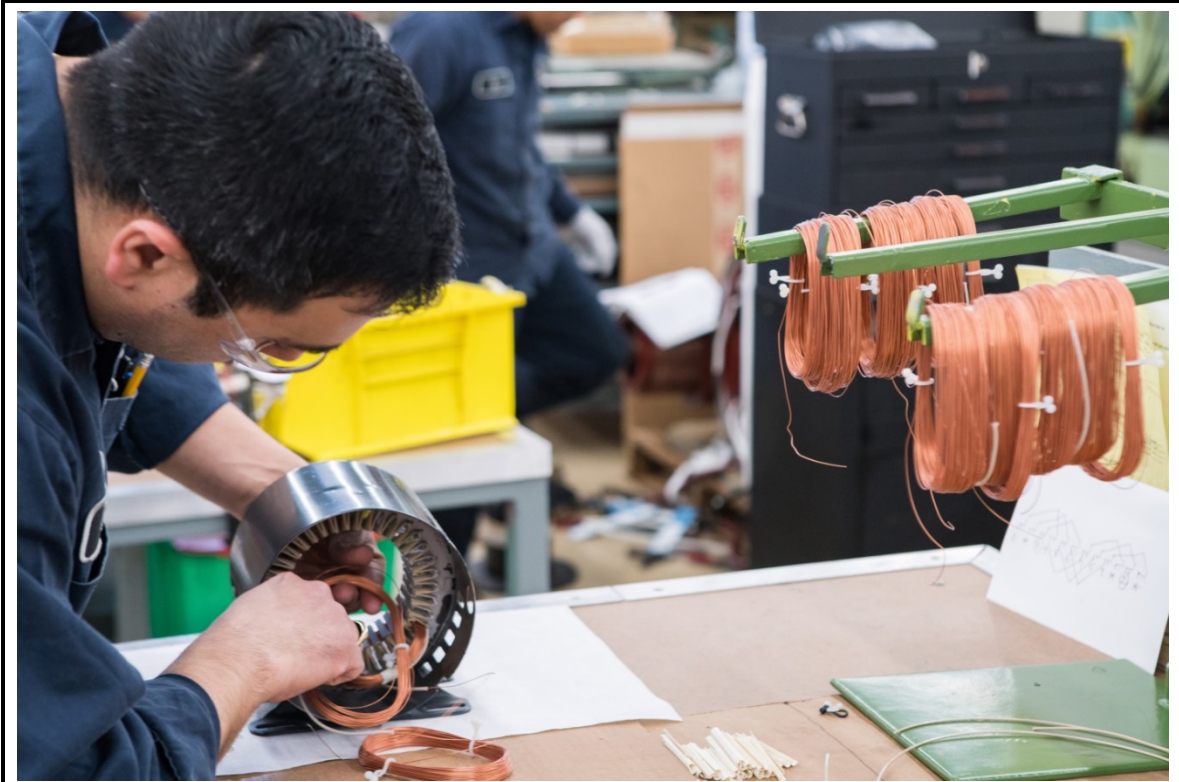


Figure 2: Installation of the PEEK windings (right) into the stator slot of the motor (left).

When the windings were tied and laced, the stiffness of the PEEK wire was again noticeable as the wire exhibited spring-back. Similarly, as described above, the PEEK magnet wire did not bend and retain its shape as easily compared to standard wire with respect to tying and lacing of the windings into the motor. Although these issues initially required gaining some familiarity on the part of the operator, they posed no concern regarding the operation of the motor itself. With appropriate lacing and tie cord application, the end windings were easily secured. Additionally, the PEEK magnet wire was found not to kink readily; this aspect is a preferred trait when handling wire for applications such as described here.

Other aspects of the PEEK magnet wire, such as slip, manufacturability, lubricity, cut through resistance, and formability were all equal to or better than standard magnet wire. The new PEEK magnet wire should be able to be adapted to manufacturing environments with minimal difficulty.

SLOT AND PHASE INSULATION

The use of PEEK Lay-Flat® tubing material for phase and slot insulation was also investigated as a replacement for traditional Nomex®, Nomex® laminate, and Dacron®-Mylar®-Dacron® (DMD) type insulation (**Fig. 3**). 9 mil Lay-Flat tubing was used for the slot liner,

whereas 11 mil Lay-Flat tubing extrusion was used as phase separation material. These specifications matched the original material thicknesses of Nomex® laminate insulation which was Nomex®-Mylar®-Nomex® (NMN) 3-3-3 for the slot and NMN 3-5-3 for the phase material. Nomex® wedge material was used in both the original motor and the rewind motor.

For use as a slot liner, installation of the PEEK Lay-Flat® was comparable to the installation of the standard Nomex®. While there was a familiarization period when initially handling the PEEK Lay-Flat® material (as similarly described for the PEEK-coated Magnet wire above), the operator quickly acquainted himself with the new material's attributes, and installation of the phase and slot insulation continued without further concern.

In typical motor manufacturing, to protect the newly installed magnet wire from the sharp edges at the slot exit during the winding process, the slot liner material is typically extended beyond the end of the slot and bent over the outer edges at the slot exit to form a cuff. Like the Nomex® material, the operator was able to use the standard method (hand forming) with the PEEK Lay-Flat® material when creating the cuff. Likewise, the operator was able to use their normal foot-operated mechanical shear to cut the PEEK to length and width. To increase the overall speed of installation of the PEEK Lay-Flat®, pre-forming of the slot liner is recommended to create a slot liner which more closely conforms to the slot. This operation would thus facilitate the magnet wire winding insertion process.

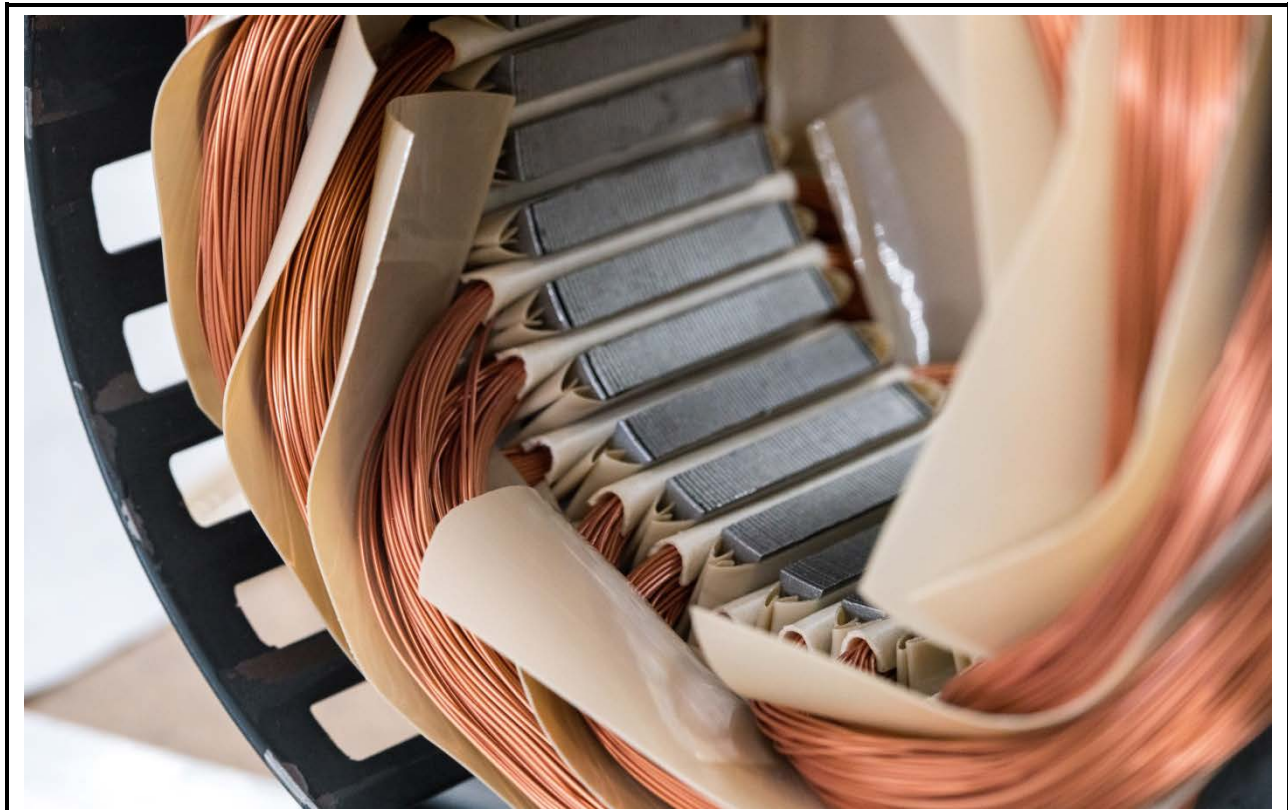


Figure 3: Completed stator winding with PEEK magnet wire, PEEK Lay-Flat® slot insulation, PEEK Lay-Flat® phase insulation, and Nomex® wedges.

During installation of the PEEK Lay-Flat®, the operator made the observation that the cut edges of this material did not possess the same degree of softness as the laminate due to the plastic nature of the PEEK compared to the softer cloth-like Nomex® and laminate materials. However, excess PEEK Lay-Flat® material was easily removed from the end of the winding area by cutting the phase insulation with scissors into the curve shape necessary for application. Thus, the final result was that using PEEK Lay-Flat® for phase insulation was no different than using the standard Nomex® and laminate material. This process may be improved for production purposes by using materials pre-cut to the size and shape needed for phase insulation thereby increasing production through-put.

RESIN IMPREGNATION

The completed stator was impregnated through a trickle varnish process using standard polyester resin with conventional processing techniques (**Fig. 4**). The trickle process used a pre-catalyzed resin and was slowly poured onto the end winding section of a heated stator. The resin was allowed to flow into the stator slots through gravity and capillary processes. The resin was allowed to cure *in situ* as the stator was rotated and additional resin introduced. The process required approximately an hour to complete.

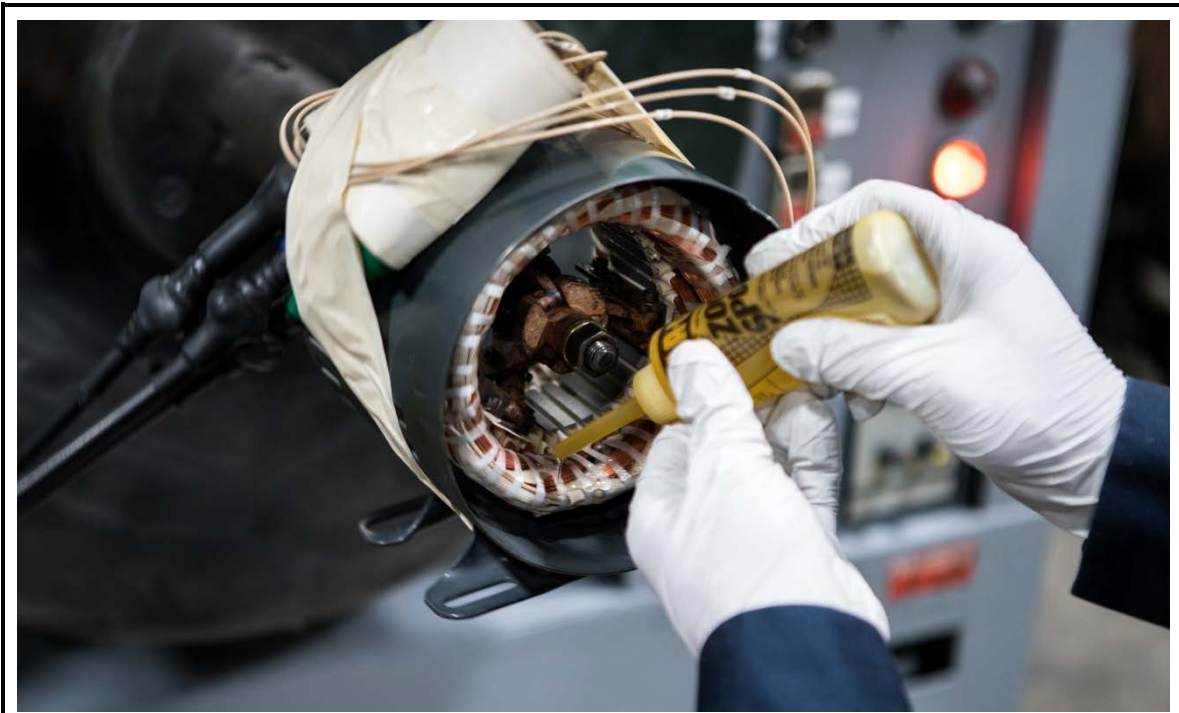


Figure 4: Impregnation of the stator windings with trickle varnish resin.

During the resin impregnation process at the production plant, no difference was noted following installation of the PEEK magnet wire and PEEK slot and phase insulation material. The trickle resin flowed into the slots and covered the end windings as typical for a rewind operation.

Upon cross-sectioning of the motor following resin impregnation and subsequent testing, areas of inadequate resin retention were observed in the end winding region in the form of large open voids (**Fig. 5**). These voids could be averted in the future through improvements to the winding process or by adjustments to the trickle resin

application procedure to facilitate resin retention. After resin impregnation, there was essentially no partial discharge (PD) activity noted in follow-up the electrical testing. Conversely, considerable PD was observed prior to rewind using conventional magnet wire and phase insulating material. Furthermore, and as described at the outset of this report, the motor used for this rewind and evaluation was a new “off-the-shelf” motor with no modifications. The impregnation results indicate that although there were voids present and large in size in the motor end windings, they were of no imminent concern regarding motor performance. Likewise, the presence of voids may also have been partly due to the manufacturing process which was not optimized to minimize such voids.

SUMMARY

PEEK magnet wire was found to be somewhat stiffer or more rigid than traditional enameled Magnet wire. This characteristic of PEEK magnet wire, however, enhances the motor’s ability to withstand motion to the coil, particularly upon start up and surge conditions when the end windings are likely to experience the greatest movement. Despite the different characteristics of PEEK, following a brief period of familiarity, operators were able to quickly adapt their production techniques and use of PEEK magnet wire with no further limitations.

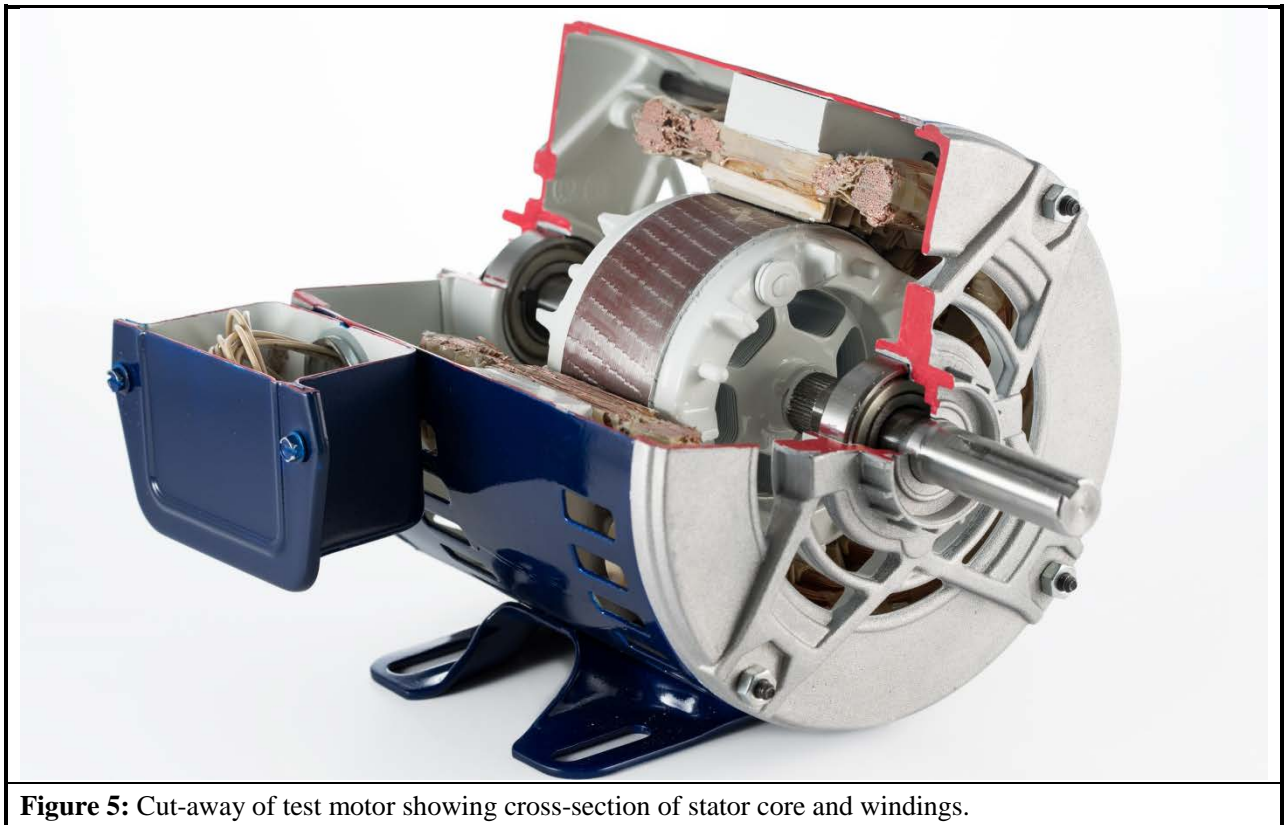


Figure 5: Cut-away of test motor showing cross-section of stator core and windings.

The PEEK Lay-Flat® material exhibited better tear resistance than standard slot and phase materials. The PEEK Lay-Flat®, however, did not exhibit the same degree of softness as the Nomex® material. The Lay-Flat was easily cut to shape and size, and the cuff at the end of the stator slot was readily formed and retained its shape. Both the PEEK Lay-Flat® and PEEK magnet wire handled differently than conventional and well known materials, but following a brief period of operator familiarity, adjusting to these different characteristics was of no further concern regarding production floor practices.

The final motor displayed excellent qualities regarding appearance and exhibited a solid end winding and superior final electrical performance. At this time, a possible barrier to implementation within a market may be the transition of operators away from standard or more commonly used materials and to the slightly different manufacturing handling characteristics of the PEEK magnet wire and Lay-Flat materials. This obstacle, however, is a natural aspect when transitioning to new production materials, and the implementation of PEEK magnet wire and Lay-Flat products into the manufacturing environment should require no new tooling and minimal education of new techniques.