Zylon: Tougher Than a Bullet Proof Vest!!

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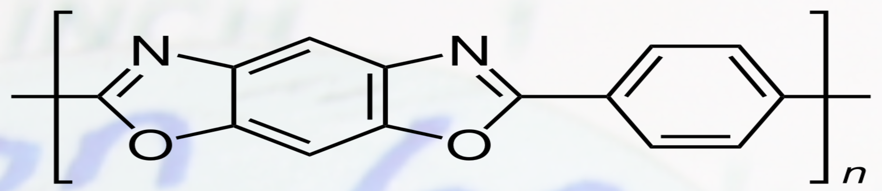
Introduction

Zylon
(Polybenzoxazole)



Zylon is an organic compound that is typically fabricated into strands of approximately 10 microns or about 10 times finer than a human hair. Zylon was invented and developed in the 1980s, which is a commercially available polymer material with extremely high ultimate tensile strength (UTS), high elastic modulus and good electrical insolation, making it the strongest man-made fiber in the world.
Zylon is flame resistant. It require 68% oxygen to burn (which is not natural in Earth's atmosphere). Zylon has high thermal stability, which will decompose only at temperatures in excess of 1470°Fahrenheit/ 798.9°Celsius. Zylon has many uses because of its fore mention characteristics. Its flame resistance is ideal for fire fighting gear, and high energy absorption for ballistic protection. This non-destructive wire-wound coils is being tested to determine if is can withstand the expansion stress caused by energy flowing through the magnet.

Purpose

The reason for wanting to use such a material as Zylon in the pulsed magnets is because of the mechanical properties. Using Zylon has been ideal for records in pulsed magnetic fields in up to 100T (Tesla), which require very high strength of the construction materials.
When examining the Zylon fibers our task is to identify the number of filament within a given area. Once the number of filaments are identified we are able to determine the packing factor of each section according to the amount of tension. This information is important to the engineers in deciding which amount of tension should be used when winding the pulsed magnets to produce the best outcome.

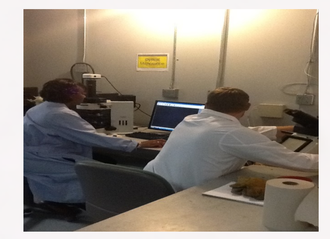
Zylon is wrapped around a winding which includes of glass fiber, Zylon fibers, and epoxy composite.

Procedure

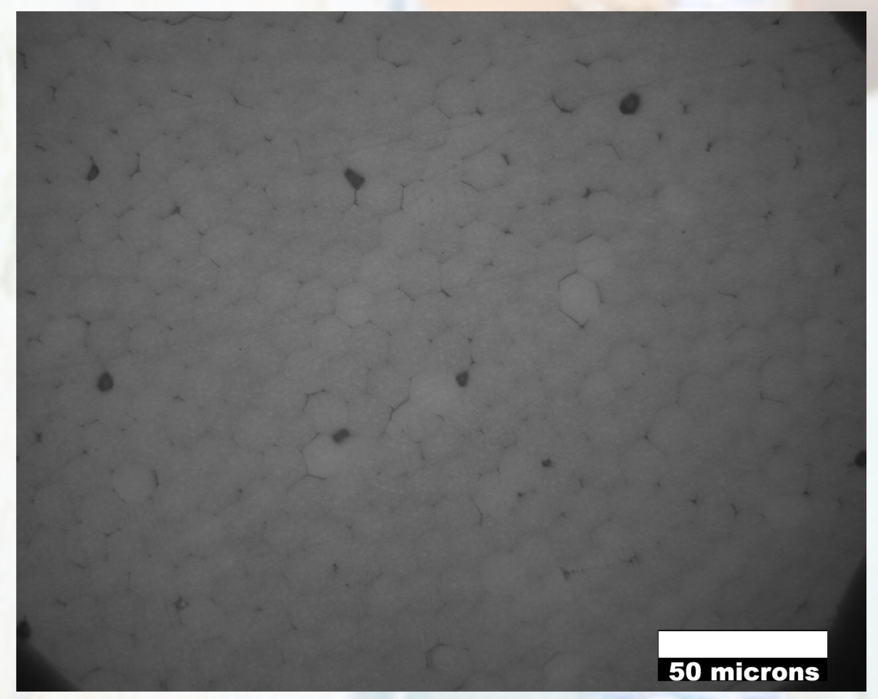
Step 1: Cut the Zylon based fiber samples from the winding.

Step 2: Mount sample using bakelite molding. (Total time 22 min)

Step 3: Grind using 800, 1200, 2400 grit paper.
Step 4: Micro polish using 9 and 3 micron diamond paste.



Step 5: Obtain images (inside, interior, outside) within the Zylon fibers using the metallograph.

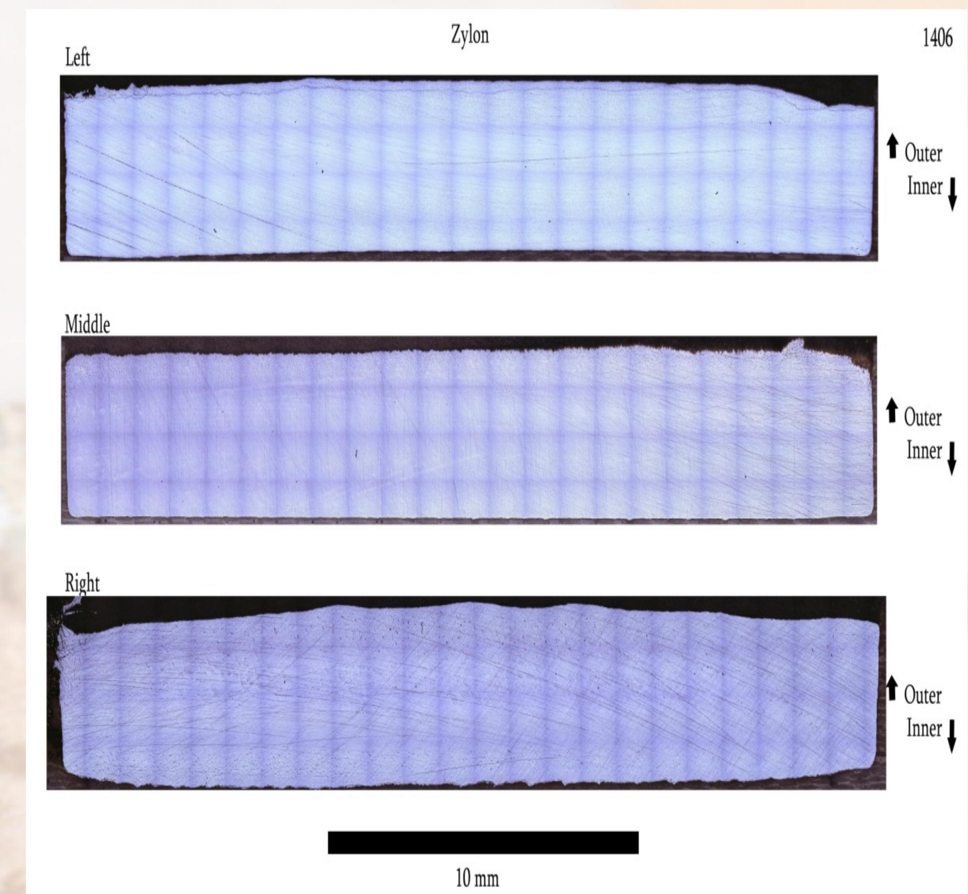


Step 6: Use Adobe Photoshop and Image J to identify filaments to determine packing factor.

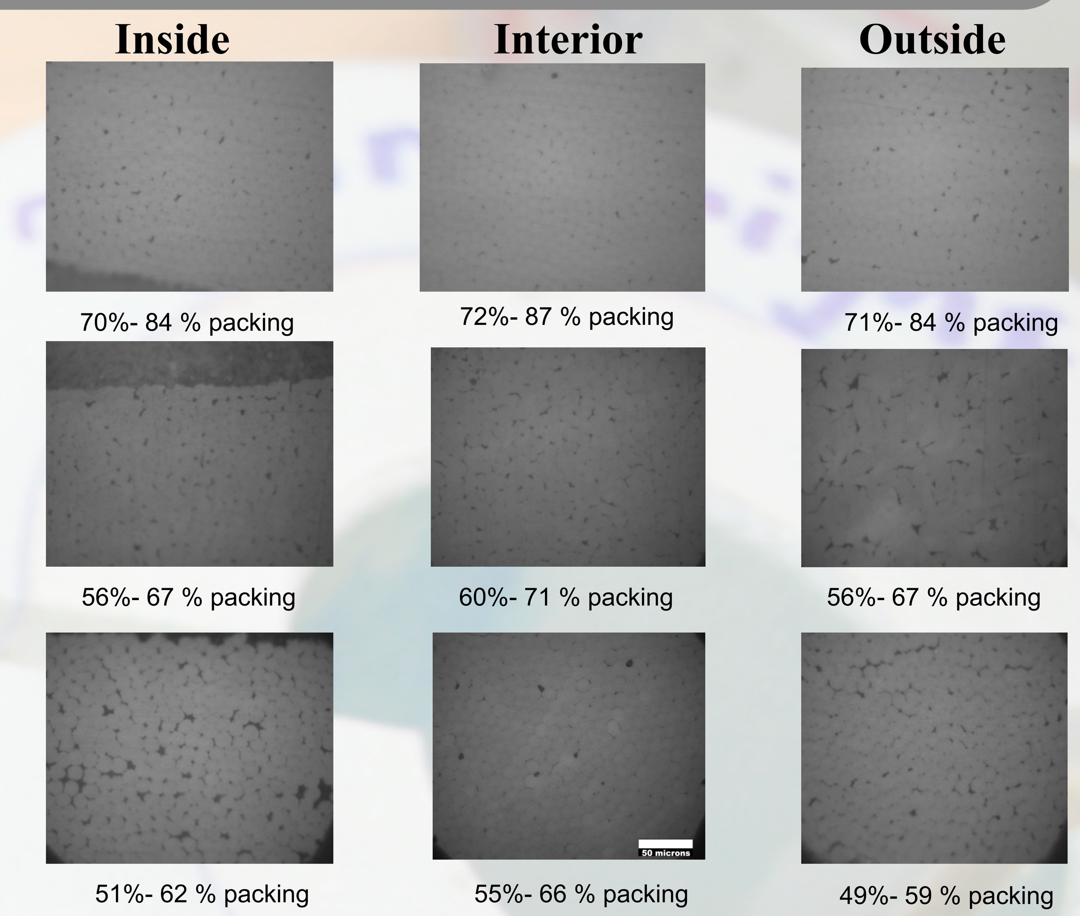
Results and Discussion

While prepping and polishing the Zylon samples, the question is whether an accurate packing factor, based on metallographic polishing, can be obtained? After polishing and examining the fibers with the metallographic microscope, the determination is that an exact packing factor was not possible for multiple reasons. The primary reason for the unreliable packing is due to the heads of the filaments flaring out causing a mushrooming effect where void spaces are not correctly identifiable. Adding to this, the non-standard diameter of each filament makes it difficult to get an accurate size and count. Reports show that the Zylon filaments range between 11 – 12 microns. Our analysis showed that the Zylon filaments actually ranged between 8.25 – 11.8 microns. The secondary reason is that the epoxy does not adhere well to the Zylon fibers during the winding process thus reducing the ability to hold the fibers tightly together. The Zylon/epoxy composite is desirable because it keeps the fibers from stretching; therefore not having the appropriate ratio of Zylon/epoxy composite mixture can result in a lower packing factor.

Results and Discussion cont.



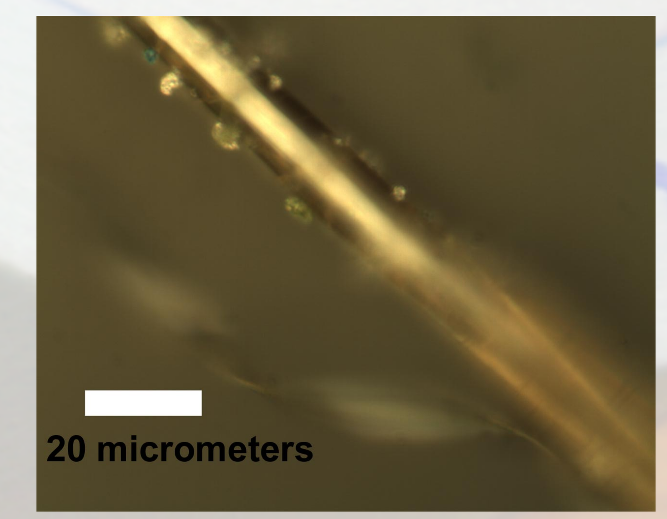
Micrograph cross-sections of Zylon spool windings



Expanded Zylon micrograph

Conclusion

When winding the magnets the amount of tension plays a significant role in the magnets overall functionality. When wound with low tension the distribution of the Zylon is not uniformed resulting in more void space. The effect of the highest tension while winding causes evenly distributed fibers resulting in a higher packing factor between 70% to 87%. The higher tension may not be able to withstand the stresses from the pulsed magnet even though distribution of the fibers will be more uniform. In view of the structure and the stress state of a magnet, the fiber-wound Zylon/epoxy composite is suitable as reinforcement material for the high-field magnet coils because of its very high ultimate tensile strength (UTS) along the fiber direction. Therefore microanalysis of the Zylon/epoxy composite is necessary to provide information about the mechanical properties for engineers to decide whether this material will be suitable for a 150 T pulsed magnet.



Optical microscope image of Zylon fiber adhered to epoxy.

Resources/ Acknowledgements

- Zylon. Retrieved from: toyobo-global.com
- Huang, Y. Mechanical properties of Zylon/epoxy composite. Physica B Condensed Matter 2001; 294(4):657-660.
- Yabuki K. Poly(p-phenylenebenzobisoxazole) Fiber. 12th Annual Meeting, Polymer Processing Society, Sorrento, Italy, May 27-31, 1996, p.279.
- Natsuhara T. PBO Fiber "ZYLON". Kako Gijutsu (Processing Technology) 1996;31(9):566.

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