On the probability distribution for midplane shorts

Moyses Kuchnir
March 6, 1991

The midplane shorts developped in the long 40 mm-magnets fabricated at Fermilab are mainly between the inner coils. This distribution has been a baffling puzzle since the pressing operations (coil forming, collaring and yoking) do not stress the the inner coils more than the outer coils in a first approximation. In this note evidence and reasoning are presented that could account for this asymmetry.

A series of microscopic observations of the .001" thick Kapton tape wrapping the cable were made[1]. They revealed that microtears show up preferentially in regions where this tape has been stretched. These microtears can develop into spark gaps leading to shorts. One such periodic region is the bending region where the half lapping leaves only one tape thickness surrounding the cable.

This tape when unwrapped from a cable not yet subjected to the pressing operations presents very strong imprints from the cable edges and also fainter deformations corresponding to the periodic regions described above but, surprisingly, only for the ones corresponding to just one side of the cable. It is reasonable to infer that these fainter deformations are caused by local pre-stretching.

What could cause local pre-stretching on just one side of the cable? The worn traction rubber cleats of the wrapping machine might be its cause if the cleats of the one belt are softer then the ones of the other belt. But a more reasonable cause of this faint pre-stretching is the spooling of the cable. The friction of the overlapped Kapton concentrates the pre-stretching to the periodic regions described above and only the external (away from the reel hub) face of the cable is subjected to it. This effect being more pronounced closer to the hub of the reel where the radius of curvature is smaller.

The long coil winding operation at Fermilab preserves the external face from spool to coil for the inner coils but reverses it (external face from spool to internal face of coil) for the outer coil[2]. So only the inner coils will have pre-stretched Kapton facing pre-stretched Kapton at the midplane. In the outer coils the pre-stretched Kapton faces are directed towards the keys. Furthermore the coil winding operation starting near the keys will cause the midplane region to be formed with cable coming from closer to the hub of the spool, i. e. cable which was subjected to stronger pre-stretching.

In conclusion, it is reasonable to expect a higher probability for the midplane shorts to be between inner coils than between outer coils.

References:
[1] Richard Sims, private communication
[2] Reid Rihel, private communication