Fermilab

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MEMO TO: Randy Rieken

FROM: Jim Strait

SUBJECT: Yoking Press Capacity and Yoke Split Direction

Since we didn't get to discuss this in person while I was in San Diego, I thought I would put it in writing. The yoking tooling and press are used to hold the magnet in its desired mechanical state, which is then "locked in" when the shell is welded. The tooling which "cradles" the magnet and the bed on which the tooling sits (the lower press platen) are surveyed to be straight and flat to the required tolerance. In production presumably the desired sagitta would be put into the tooling and thereby define the magnet shape. In the Fermilab design the full length alignment key interlocks with the tooling to hold the internal structure of the magnet in a twist-free state.

Because there is an interference fit between the yoke and collars, gaps appear in the magnet (yoke-yoke and yoke-collar along the yoke-split direction) at assembly that are not present after the shell is tensioned by the weld shrinkage. Because of manufacturing tolerances the half shells can not be guaranteed to conform to the yoke before shell welding and therefore the yoked magnet may not be seated firmly in the tooling that will define its final shape. The yoking press serves to eliminate all these gaps before shell welding, which puts the entire structure in a state approximating its final configuration to a high accuracy.

Thus the yoking tooling serves three related functions: 1) to cause the shell to conform to the yoke, 2) to seat the magnet positively in the tooling and 3) to close the yoke-yoke and yoke-collar gaps to their final dimensions before welding. The load required to accomplish the first two objectives are considerably lower than that for the third objective. We have chosen to use a press load equivalent to the clamping force of the shell after welding:

$$30 \text{ kpsi} \times 2 \times 0.2 \text{ inches} = 12000 \text{ lb./in.}$$

None of this discussion depends on the yoke split direction and similar loads have been used for both horizontally (40mm) and vertically (40mm and 50mm) split yoke magnets built at Fermilab. The load actually required to close the yoke gap is calculated and measured to be only about half this much for typical vertically split yoke 50mm magnets. The load required to close the yoke gap in our 40mm horizontally split yoke magnets (whose design is discussed in "Calculation of Desired Vertical Ovality of SSC Collars" which is included in the book I gave Steve Pidcoe) is larger than that required for our vertically split models. (This is because the collared coil is more compliant when compressed horizontally while being left free vertically - the vertically split yoke design - than when compressed vertically while being constrained about its full circumference - the horizontally split yoke design.)

While it is our belief that holding the magnet in its final configuration prior to welding is the correct procedure irrespective of the yoke split direction, it is perhaps debatable whether or not it is required to close the yoke-yoke gap prior to welding. The weld shrinkage applied shell tension will close the yoke gap in our design independent of the press load, and it is likely that if before welding the components are properly aligned by the tooling, up to the open yoke gap, then the magnet will be structurally correct after welding. (There is, of course, the risk that this will build in stress asymmetries and therefore stress gradients due to asymmetric initial conditions. Redistribution of the stresses at some later point, for example during cooldown or excitation, may have unknown and perhaps undesirable effects.) In fact, the first vertically split yoke model we made (a rebuild of BNL's DSS012) was assembled before we had commissioned our yoking press. A clamping structure using pairs of 1" bolts on 12" centers, which could apply a load trivial compared to the press, was used instead. Strain gauge measurements showed that this magnet performed as expected and the yoke gap remained closed up to at least 7 T, the highest field measured. (Data from this magnet are discussed in the paper "Experimental Evaluation of Vertically Versus Horizontally Split Yokes for SSC Dipole Magnets," which is in the book I gave Steve.)

In summary, we believe that the capacity of the yoking press is not related to the split direction of the yoke and therefore a desire to limit the capital cost of the press should not cause you to reject the vertically split design. There are certainly good arguments for and against each design, but this is not one of them. If you would like to discuss this or any other issues of magnet design and assembly methods, please feel free to call me at (708) 840-2240 or fax me at (708) 840-3756.

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