Magnetic field calculations

First of all, thank you very much for your calculations. Unfortunately, it looks that only one iteration of such calculations was made. ANSYS gives an averaged result that is stated in its Manual. In your report "BSUM (AVG)" can be seen in the Figures of the pages 11-12.

The analysis has been solved using the ANSYS macro *magsolv* which performs all the needed iterations. The plot reports "BSUM (AVG)" as a consequence of the fact that it is the result of a *plnsol,b,sum* command. Looking in the manual at the *plnsol* command you can find:

"Contours are determined by linear interpolation within each element from the nodal values, which are averaged at a node whenever two or more elements connect to the same node (except for FMAG, which is summed at the node)."

Three items are obvious:

1) The ANSYS 3D was made by Yuri Gussakov in September 2017 upon our request. The maximal field on the SC winding was confirmed to be 3.85 T. Our Mermaid code gave it value (3.91 T) immediately in June 2017. So, there are two ANSYS 3D calculations with different results.

Since another ANSYS model was made it would be interesting to compare more closely our results. Could you produce a report like the one I did with some explanations of the model and the mesh and some field plots? Which element did you use? How many nodes? Did you check the field along the x axis?

Concerning the peak magnetic field, the value you found is conservative so I agree you should keep using yours.

2) The azimuthal behavior of the vertical force was our concern also. The magnetic field was compared between Mermad 3D and ANSYS 2D along six different lines inside the SC winding at 4 three places with azimuthal angles of 0° 45° and 90°. This report was made in January 2018. The difference was always below 10%. So, the vertical force will have also the same difference as the Lorentz force dependent on current and magnetic field. The last figure of your report has magnetic field distribution in the SC winding. It does not look like to have 40% difference of the magnetic field in it.

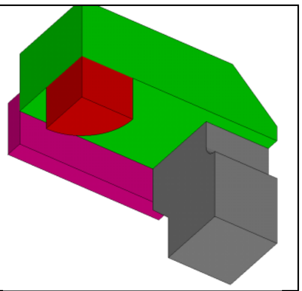
I confirm my findings on the azimuthal behavior of Fz. The maximum value (positioned on the x axis in your coordinates) is around 30% larger than the minimum value (positioned on the y axis). Since $Fz \propto BrJ\theta$, you should look at the local variation of Br, which are not noticeable in Bsum plots.

3) The forces on the yoke. The vertical force on the poles is important to know because this pole will be held by 6 bolts. The horizontal blocks will not bend by the huge forces because this force is between the adjacent coil and this block. The summary vertical force acting on assembled coil and the horizontal block should be ~ 10 times less, because the coils almost do not feel each other – mutual inductance is low.

In the Tab. III there is no force on the Pillars. That is strange because any iron should be attracted inside the magnet. The Pillars do not have symmetrical configuration which may compensate the forces. ANSYS demands that for the force calculations for any iron parts these parts should be separated by air gaps. It looks that problem is here.

To calculate the magnetic force I made a special analysis using the new *solid236* element which does not require air gaps to calculate the magnetic forces in iron components (using the macro EMFT). The zeros in the table depend on the fact that I choose to show forces with only 1 digit, and forces in pillars are well below 0.1 MN. Also, some of the values (Fx and Fy) where not reported correctly. The correct values in 1/8 symmetry are in the following table. Fz values are confirmed (Fz values in the table below should be multiplied by 4 to get Fz forces in ½ symmetry).

Forces in 1/8 symmetry, as shown in the picture:

	POLE (red)	ROOF (green)	PILLARS (grey)	SIDE BARS (pink)	TOTAL	
Fx (MN)	0.243	-0.111	-0.0066	-0.005	0.1204	
Fy (MN)	0.255	-0.111	-0.0003	-0.049	0.0947	
Fz (MN)	-0.637	-0.360	0.0004	-0.045	-1.0416	

The question about discrepancy between Mermaid and the ANSYS 3D around the field clamps looks less important. May be Mermaid has bad mesh density. I'll check it later.

I agree it should have a secondary importance but it could reflect a mismatch in the iron geometry.

The vertical force of 3.4 MN value will be taken into account. The Gussakov's calculations also presented higher value 3.1 MN than in the CDR report which is 2.6 MN.

Ok to take into account the most conservative value.

Further comments:

1. I strongly suggest including in the structural analysis the force distribution coming from the electromagnetic analysis. A uniform distribution leads to an underestimation of stresses and strains.

2. Despite the fact that, in a perfectly symmetric system, horizontal forces should be null, in real life horizontal forces will be present and there has to be a mechanical system able to withstand them. You should at least evaluate the effect of a non-perfect positioning of the coil.