D1 Cold Transfer Function: HCMBX   001-BL00000x

Five of these single aperture magnets were produced and they will be used in the D1 position next to ALICE and LHCb. Only two magnets were measured cold, D1L101 and D1L103. However, D1L101 is not completely representative since it contains stainless steel yoke keys instead of steel.
First of all, define some "constants"

$Iinj := 400 \qquad Inom := 6000 \qquad Ic := 7000$

The geometric term is estimated to be

$\gamma := 0.006752523$

The TF data was measured at 4.5K

data :=

	0	1
0	50.85	$6.756\cdot10^{-3}$
1	100.834	$6.668\cdot10^{-3}$
2	200.615	$6.658\cdot10^{-3}$
3	300.565	$6.665\cdot10^{-3}$
4	350.504	$6.668\cdot10^{-3}$
5	400.493	$6.67\cdot10^{-3}$
6	600.231	$6.675\cdot10^{-3}$
7	799.804	...

$current := data^{\langle 0\rangle}$

$TF := data^{\langle 1\rangle}$

$temp1 := TF - \gamma$

$dataA := augment(current, temp1, TF)$

DC Component - Saturation

Prepare the data to fit between 2000A and Inom. Scale the TF by 10^5 to improve conditioning

$saturation^{\langle 0\rangle} := submatrix(dataA, 13, 33, 0, 0)$

$saturation^{\langle 1\rangle} := submatrix(dataA, 13, 33, 1, 1)\cdot 100000$

$Xs := saturation^{\langle 0\rangle} \qquad Ys := saturation^{\langle 1\rangle}$

Define the saturation function model (EDMS 908232)

$$fsat(I,\sigma,S,I0) := \sigma \cdot \left[\frac{\operatorname{atan}\left[S \cdot \left[\frac{(I - I0)}{Inom}\right]\right]}{\pi} + 0.5\right]$$

Define a vector of guesses for the fit.

$$guess1 := \begin{pmatrix} 0 \\ 0 \\ 1000 \end{pmatrix}$$

Use **genfit** to find the parameters in the model function.

$$sat := genfit(Xs, Ys, guess1, fsat)$$

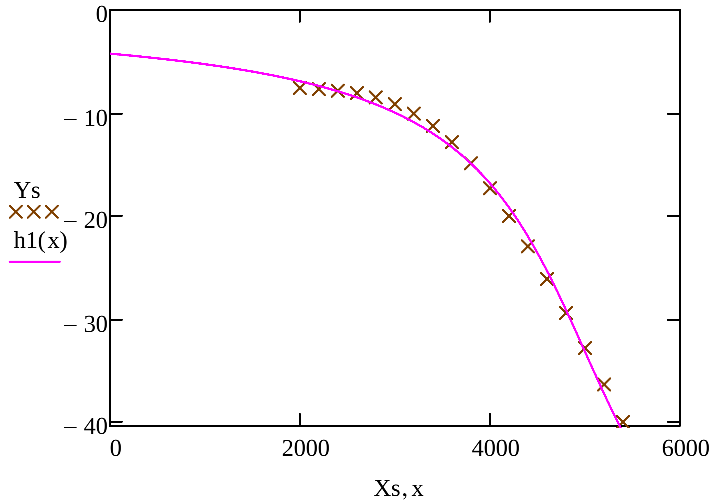
Here are the fitted coefficients for the saturation.

$$sat = \begin{pmatrix} -66.306 \\ 5.858 \\ 4.996 \times 10^{3} \end{pmatrix}$$

Define a function using these coefficients

$$h1(x) := sat_0 \cdot \left[\frac{\operatorname{atan}\left[sat_1 \cdot \left[\frac{\left(x - sat_2\right)}{Inom}\right]\right]}{\pi} + 0.5\right]$$

and plot the fitted function together with the original data (minus the geometric)


0
− 10
− 20
− 30
− 40
0
2000
4000
6000
Xs, x
Ys
h1(x)

DC Component - Persistent Currents

Prepare the data to fit between 200A and Inom. Fit against the TF-geom-saturation.
Remenber to scale the saturation function by 10^-5 !!

$$pers^{\langle 0 \rangle} := \text{submatrix}(dataA, 2, 33, 0, 0)$$

$$Xp := pers^{\langle 0 \rangle}$$

$$pers^{\langle 1 \rangle} := \text{submatrix}(dataA, 2, 33, 1, 1) - h1(Xp) \cdot 0.00001$$

$$Yp := pers^{\langle 1 \rangle}$$

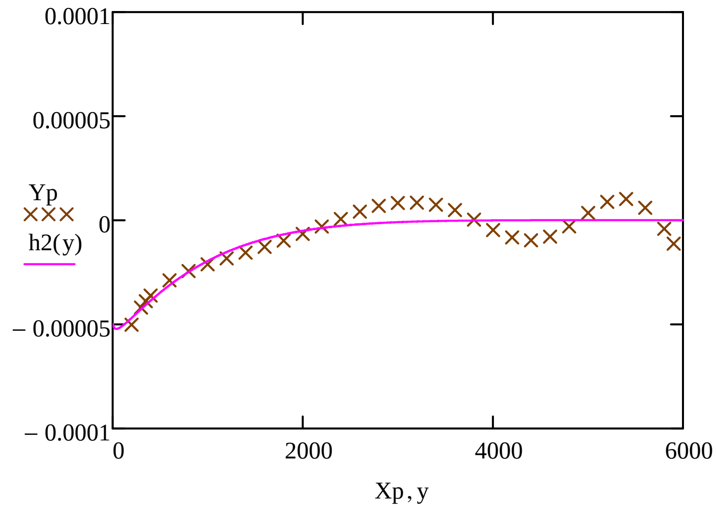
$$fper(I, \mu, p, q) := \mu \cdot \left(\frac{Iinj}{I}\right)\left(\frac{I}{Iinj}\right)^{p}\left(\frac{Ic - I}{Ic - Iinj}\right)^{q}$$

$$guessp := \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

$$per := \text{genfit}(Xp, Yp, guessp, fper)$$

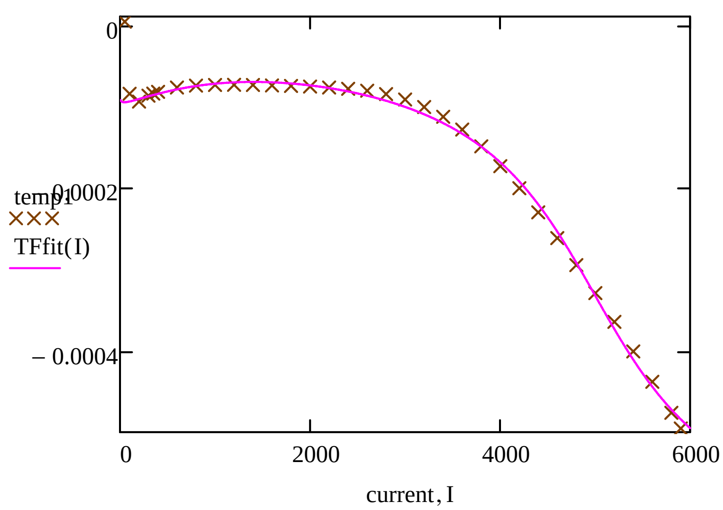
$$per = \begin{pmatrix} -3.87 \times 10^{-5} \\ 1.043 \\ 7.533 \end{pmatrix}$$

$$h2(y) := per_{0}\left(\frac{Iinj}{y}\right)\left(\frac{y}{Iinj}\right)^{per_{1}}\left(\frac{Ic - y}{Ic - Iinj}\right)^{per_{2}}$$



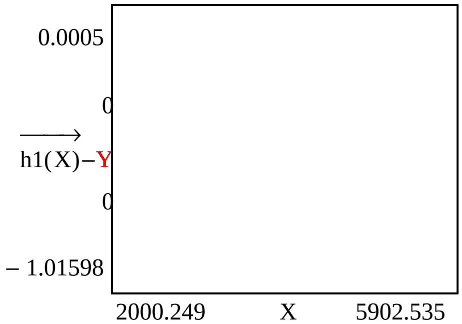
Compute the complete fitted transfer function

$$TFfit(I) := 0.00001\ sat_0 \cdot \left[\frac{atan\left[sat_1 \cdot \left[\frac{(I - sat_2)}{Inom} \right] \right]}{\pi} + 0.5 \right] + per_0 \left(\frac{Iinj}{I} \right) \left(\frac{I}{Iinj} \right)^{per_1} \left(\frac{Ic - I}{Ic - Iinj} \right)^{per_2}$$



The smallest residual values are $\min\left(\overrightarrow{h1(X)} - Y\right) = \blacksquare$

The largest residual values are $\max\left(\overrightarrow{h1(X)} - Y\right) = \blacksquare$



Calculate the correlation coefficients, however, and the fit seems much better than the residual plot might reveal.

$$\mathrm{corr}\left(\overrightarrow{h1(X)}, Y\right) = \blacksquare$$

$$\mathrm{fres}(I, \rho, r, \mathrm{offs}) := \rho \cdot \left(\frac{\mathrm{Iinj}}{I}\right)^{r} + \mathrm{offs}$$

$$\mathrm{guessr} := \begin{pmatrix} 0 \\ 0 \\ -0.0001 \end{pmatrix}$$

$$\mathrm{res} := \mathrm{genfit}(D, E, \mathrm{guessr}, \mathrm{fres})$$

$$h3(z) := \mathrm{res}_0 \cdot \left(\frac{\mathrm{Iinj}}{z}\right)^{\mathrm{res}_1} + \mathrm{res}_2$$

temp1 =

	0
0	$3.565 \cdot 10^{-6}$
1	$-8.492 \cdot 10^{-5}$
2	$-9.463 \cdot 10^{-5}$
3	$-8.735 \cdot 10^{-5}$
4	$-8.476 \cdot 10^{-5}$
5	$-8.255 \cdot 10^{-5}$
6	$-7.724 \cdot 10^{-5}$
7	$-7.501 \cdot 10^{-5}$
8	$-7.417 \cdot 10^{-5}$
9	$-7.402 \cdot 10^{-5}$
10	$-7.416 \cdot 10^{-5}$
11	$-7.464 \cdot 10^{-5}$
12	$-7.531 \cdot 10^{-5}$
13	$-7.613 \cdot 10^{-5}$
14	$-7.725 \cdot 10^{-5}$
15	...

dataA =

	0	1	2
0	50.85	$3.565 \cdot 10^{-6}$	6.756·
1	100.834	$-8.492 \cdot 10^{-5}$	6.668·
2	200.615	$-9.463 \cdot 10^{-5}$	6.658·
3	300.565	$-8.735 \cdot 10^{-5}$	6.665·
4	350.504	$-8.476 \cdot 10^{-5}$	6.668·
5	400.493	$-8.255 \cdot 10^{-5}$	6.67·
6	600.231	$-7.724 \cdot 10^{-5}$	6.675·
7	799.804	$-7.501 \cdot 10^{-5}$	6.678·
8	999.853	$-7.417 \cdot 10^{-5}$	6.678·
9	$1.2 \cdot 10^{3}$	$-7.402 \cdot 10^{-5}$	6.679·
10	$1.4 \cdot 10^{3}$	$-7.416 \cdot 10^{-5}$	6.678·
11	$1.6 \cdot 10^{3}$	$-7.464 \cdot 10^{-5}$	6.678·
12	$1.8 \cdot 10^{3}$	$-7.531 \cdot 10^{-5}$	6.677·
13	$2 \cdot 10^{3}$	$-7.613 \cdot 10^{-5}$	6.676·
14	$2.201 \cdot 10^{3}$	$-7.725 \cdot 10^{-5}$	6.675·
15	$2.401 \cdot 10^{3}$	$-7.881 \cdot 10^{-5}$	6.674·
16	$2.601 \cdot 10^{3}$	$-8.123 \cdot 10^{-5}$	6.671·
17	$2.801 \cdot 10^{3}$	$-8.533 \cdot 10^{-5}$	6.667·
18	$3.002 \cdot 10^{3}$	$-9.193 \cdot 10^{-5}$	6.661·
19	$3.202 \cdot 10^{3}$	$-1.011 \cdot 10^{-4}$	6.651·
20	$3.402 \cdot 10^{3}$	$-1.132 \cdot 10^{-4}$	6.639·
21	$3.602 \cdot 10^{3}$	$-1.289 \cdot 10^{-4}$	6.624·
22	$3.802 \cdot 10^{3}$	$-1.495 \cdot 10^{-4}$	6.603·
23	$4.002 \cdot 10^{3}$	$-1.738 \cdot 10^{-4}$	6.579·

24	$4.202\cdot10^{3}$	$-2.008\cdot10^{-4}$	6.552·
25	$4.402\cdot10^{3}$	$-2.304\cdot10^{-4}$	6.522·
26	$4.602\cdot10^{3}$	$-2.621\cdot10^{-4}$	6.49·
27	$4.803\cdot10^{3}$	$-2.952\cdot10^{-4}$	6.457·
28	$5.003\cdot10^{3}$	$-3.295\cdot10^{-4}$	6.423·
29	$5.203\cdot10^{3}$	$-3.648\cdot10^{-4}$	6.388·
30	$5.403\cdot10^{3}$	$-4.012\cdot10^{-4}$	6.351·
31	$5.603\cdot10^{3}$	$-4.385\cdot10^{-4}$	6.314·
32	$5.803\cdot10^{3}$	$-4.765\cdot10^{-4}$	6.276·
33	$5.903\cdot10^{3}$	$-4.958\cdot10^{-4}$	6.257·
34			

saturation =

	0	1
0	$2\cdot10^{3}$	-7.613
1	$2.201\cdot10^{3}$	-7.725
2	$2.401\cdot10^{3}$	-7.881
3	$2.601\cdot10^{3}$	-8.123
4	$2.801\cdot10^{3}$	-8.533
5	$3.002\cdot10^{3}$	-9.193
6	$3.202\cdot10^{3}$	-10.113
7	$3.402\cdot10^{3}$	-11.316
8	$3.602\cdot10^{3}$	-12.89
9	$3.802\cdot10^{3}$	-14.949
10	$4.002\cdot10^{3}$	-17.376
11	$4.202\cdot10^{3}$	-20.078
12	$4.402\cdot10^{3}$	-23.039
13	$4.602\cdot10^{3}$	-26.209
14	$4.803\cdot10^{3}$	-29.522
15	$5.003\cdot10^{3}$	...

pers =

	0	1
0	200.615	$-5.021\cdot10^{-5}$
1	300.565	$-4.202\cdot10^{-5}$
2	350.504	$-3.895\cdot10^{-5}$
3	400.493	$-3.626\cdot10^{-5}$
4	600.231	$-2.892\cdot10^{-5}$
5	799.804	$-2.448\cdot10^{-5}$
6	999.853	$-2.121\cdot10^{-5}$
7	$1.2\cdot10^{3}$	$-1.839\cdot10^{-5}$
8	$1.4\cdot10^{3}$	$-1.559\cdot10^{-5}$
9	$1.6\cdot10^{3}$	$-1.281\cdot10^{-5}$
10	$1.8\cdot10^{3}$	$-9.84\cdot10^{-6}$
11	$2\cdot10^{3}$	$-6.588\cdot10^{-6}$
12	$2.201\cdot10^{3}$	$-3.11\cdot10^{-6}$
13	$2.401\cdot10^{3}$	$5.429\cdot10^{-7}$
14	$2.601\cdot10^{3}$	$4.083\cdot10^{-6}$
15	$2.801\cdot10^{3}$	...

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