**ELENA B-train Calibration**

* **Effective width calculation**

From previous measurements on PXMBHEKCWP-DA00002:

A cross-calibration between Fluxmeter 1 coil 5 (F1C5) and Fluxmeter 3 coil 5 (F3C5).

Measurements on Fluxmeter 3 coil 5, where:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Trial number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Average | |  | 2.8579 | 2.8579 | 2.8578 | 2.8579 | 2.8580 | 2.8579 | 2.8578 | 2.8580 | **2.857886** | |  | 2.84152 | 2.84145 | 2.84137 | 2.84147 | 2.84155 | 2.84144 | 2.84135 | 2.84155 | **2.841452** | |
|  |
|  |

1. The ponderationFactor and correctionFactor were set to 1, and the markers were turned off. The C0reset was turned on so that the cycle resets to zero on every C0 trigger.

2. At this stage, the B-train measures , the coil measurement including the gain of the electronics and the difference between Coil 5 and Coil 6.

For the op PBMD2 cycle: at 3.10 s. Measured = 0.3490 Tm

From offline measurements of the coil: for the spare system and for the operational system.

This brings

* **Loading effect**

It is noted here that:

Calculating uncertainty of B-train loading effect

The gain provided to compensate for the loading effect in the measurement in denoted as:

Where is the B-train’s input impedance and is the coil resistance measured using Agilent 34401A multimeter.

SPARE:

is derived from the instrument’s manual, where the accuracy at room temperature for measurements shorter than 24 hours is calculated as follows:

Where the range error is a fixed error depending on the range of the measurement (1 ) and the reading error is an error proportional to the reading.

Including the temperature coefficient:

For

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Standard uncertainty component** | **Source of uncertainty** | **Value of standard uncertainty** |  |  |
|  | Accuracy of multimeter + Temperature |  | 1.53 | 3.5 |
|  | Accuracy of multimeter + Temperature |  | 2.5 | 5.3 |

Hence, the uncertainty of the B-train loading effect is:

Therefore:

* **Marker magnetic length**

At this stage, is configured and hence C0reset is removed and the marker levels are added according to the values calculated offline:

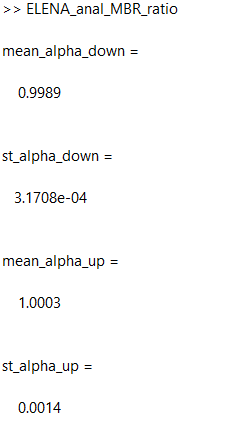
It was noticed that the markers fit in seamlessly with no bumps as expected and are marking these values (as ponderation factor is still 1).

* **Reference-to-machine error**

The scaling factor is known from offline measurements for decelerating cycle.

The scaling factor is known from offline measurements for accelerating cycle.

Stdevation based on average of three cycles:



* **Coil position error**

The coil position compensation due to lateral position error is found using a laser tracker.

The distance between the magnet’s beamline and the fluxmeter central coil is 0.119 mm (average of the displacement on both sides), with the displacement being towards the centre of the ring. From the homogeneity map of the magnet, it can be seen that at distances in that direction, the field is higher, and so the field has to be lowered, in order to reflect the field level in the centre.

Uncertainty is 0.2 mm from differences in model fit and measurements.

Hence the **ponderation factor is:**

**Uncertainty analysis**

The estimated standard deviation associated with measurement output , combined standard uncertainty , is derived from the estimated standard deviation of each input estimate , termed standard uncertainty . In the determination of the combined uncertainty, all quantities will be assumed to be independent. This is based on the notion that all quantities have been measured repeatedly but not simultaneously in different independent experiments. GUM defines as the positive square root of the combined variance given by:

where is the measurement model, and each is obtained from characterization/calibration measurements.

* **Evaluating the expanded uncertainty**

Although is in itself a universally accepted method of describing the uncertainty in a measurement, the GUM recommends the use of expanded uncertainty as a more practical way of denoting the uncertainty. The expanded uncertainty is obtained by multiplying the combined standard uncertainty by the coverage factor :

The coverage factor is a constant based on the level of confidence required. For a standard 95% confidence interval, a coverage factor of two is considered. Once this value is determined, the result of a measurement system is then expressed as. An interpretation for this expression is that the best estimate of the measurand is , and that the interval to is expected to contain a large proportion of the distribution of values that could be associated with .

**Calculating uncertainty of B-train**

The B-train measurement model is as follows:

The uncertainty function is defined as:

|  |  |  |
| --- | --- | --- |
| **Standard uncertainty component** | **Source of uncertainty** | **Value of standard uncertainty** |
|  | Assumption that is constant, when in fact it is not. | **3.17** |
|  | Precision of the laser tracker survey measuring the radial error of the fluxmeter with respect to the beam path. Combination of errors in measurement. | **1.05** |
|  | Tolerance of the input impedance of the B-train and the accuracy of the instrument used to measure the coil resistance. | **7.2e-6** |
|  | Repeatability in the measurement of | **77.1 m** |
|  | Stability of B-train electronics and fluxmeter. Repeatability of B-train measurement without markers. | **26.6** |
|  | Repeatability of NMR markers. | **12.6 Tm** |

Hence, by the linear uncertainty propagation method:

**Calculating uncertainty of B-train OLD**

The B-train measurement model is as follows:

The uncertainty function is defined as:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Standard uncertainty component** | **Source of uncertainty** | **Value of standard uncertainty** |  |  |
|  | Assumption that is constant, when in fact it is not. Consider from 35 A. | 9.355 | 0.13168+ 0.24417 | 1.1522.137 |
|  | Precision of the laser tracker survey measuring the radial error of the fluxmeter with respect to the beam path. Combination of errors in measurement. | 1.07 | 0.13133+ 0.24385 | 1.5042.792 |
|  | Tolerance of the input impedance of the B-train and the accuracy of the instrument used to measure the coil resistance. | 6.9e-6 | 0.13067 | 7.972/ 8.102 |
|  | Repeatability in the measurement of | 77.1 m | 0.01622 | 9.642 |
|  | Stability of B-train electronics and fluxmeter. Repeatability of B-train measurement without markers. | 26.6/ 26.8 | 0.13132 | 9.292/ 9.432 |
|  | Repeatability of NMR markers. | 12.6 Tm | 1.05807 | 8.898 |

Hence, by the linear uncertainty propagation method:

For at injection level: