Laboratori Nazionali di Frascati

LNF-56/25 (1956)

F. Amman, L. Dadda: DESIGN OF THE POLE FACES FOR CIRCULAR PARTICLE ACCELERATORS WITH THE ELECTROLYTIC TANK.

Estratto dal: Nuovo Cimento 3, 184 (1956)

IL NUOVO CIMENTO VOL. III, N. 1 1° Gennaio 1956

Design of the Pole Faces for Circular Particle Accelerators with the Electrolytic Tank.

F. AMMAN

Istituto Nazionale di Fisica Nucleare, Sezione Acceleratore - Roma

L. DADDA

Istituto di Elettrotecnica Generale del Politecnico - Milano

(ricevuto il 29 Novembre 1955)

Summary. — A method is presented here for the measurement of a quantity approximately proportional to the second derivative of the electric potential in the electrolytic tank. This method is very useful for the measurement of the field index n in the gap of a circular particle accelerator.

In the design of the pole faces for a circular particle accelerator, the electrolytic tank is a very helpful way to obtain the proper pole shape without an iron model.

There are many papers on this method of field mapping (¹); the main differences between the preceding methods and the one we used are:

1) We used the conjugate analogy instead of the direct analogy; in the conjugate analogy the current function in the electric current field corresponds to the magnetic potential in the magnetic field, and the electric potential corresponds to the magnetic flux function. It is possible to use the conjugate analogy only in 2-dimensional fields or in 3-dimensional fields with axial simmetry (²). We recall here that it is necessary to use the conjugate analogy

---

(¹) G. LIEBMANN: *Advances in Electronics*, **2**, 101 (1950).

(²) L. DADDA: *L'Energia Elettrica*, **30**, 837 (1953).

when we have to map portions of magnetic fields where rot $H \neq 0$ (inside the coils).

2) We measured the index n, proportional to the second derivative with respect to the abscissa r of the electric potential in the current field, directly comparing in a bridge circuit two voltages proportional to the first derivative of the electric potential; previously used techniques measured the electric potential or its first derivative and obtained the second derivative graphically.

The main advantages of this method are:

1) We directly compare two voltages in a bridge circuit, therefore the shifts in the supply voltage have no influence. By using two calibrations of the probes we can reduce very much the errors due to the measuring apparatus. In effect the second derivative of the electric potential is approximately proportional to the difference between two first derivatives, which in our case have almost the same value; with such calibrations the error of this difference has the same relative value as each term of the difference; with the graphic or analytic methods, the error of the difference has the same absolute value as in each term.

2) In the direct analogy the pole piece is represented by an equipotential surface. It is difficult to define an equipotential surface in a conducting plate placed in an electrolytic solution because of the voltage drops on its surface; since the gradient is very sensitive to the precise shape of the pole, it is therefore better to use the conjugate analogy where the pole face is insulating.

3) In the conjugate analogy B_z corresponds to $\partial V/\partial r$, and $\partial B_z/\partial r$ corresponds to $\partial^2 V/\partial r^2$, a quantity which it is possible to measure with three probes alined in the r direction. In the direct analogy B_z corresponds to $\partial V/\partial z$ and $\partial B_z/\partial r$ to $\partial^2 V/\partial r\,\partial z$: to measure the mixed derivative one needs four probes and, at least, one transformer to compare the two voltages, as there are no points at the same potential.

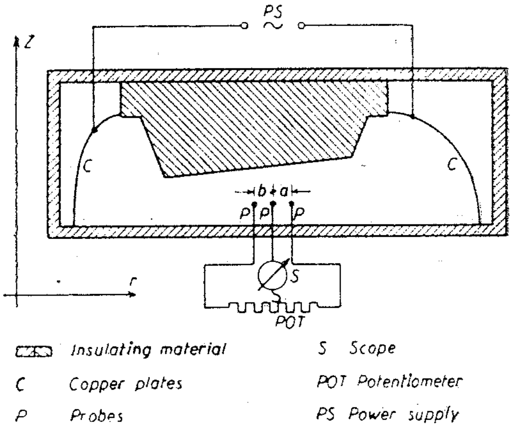

Fig. 7.

The schematic circuit we used for these measurement is sketched in Fig. 1.

The index n, defined in a magnetic field as

$$n = -\frac{\delta B_z}{\delta r} \cdot \frac{r}{B_z} \tag{1}$$

is given in the conjugate analogy by

$$n = -\frac{4r}{a+b}\,\frac{V_1/V_2 - a/b}{V_1/V_2 + a/b}, \tag{2}$$

where V_1 is the voltage across the length a, and V_2 the voltage across b, a and b being the distances between the two outside probes and the inner one.

The formula (2) holds for 2-dimensional fields; in the case of 3-dimensional fields with axial simmetry, there is another term, and (2) becomes

$$n = -\frac{4r}{a+b}\,\frac{V_1/V_2 - a/b}{V/_1V_2 + a/b} + 1\,. \tag{3}$$

The obtain n we have therefore to measure three quantities: two ratios, V_1/V_2 and a/b, and the value of $a+b$.

The first ratio is measured with the probes in the model; the second ratio is measured putting the probes in a uniform field, and this is the first calibration.

The best way to measure the quantity $a+b$ is to calibrate the probes in a known current field, whose gradient is not constant; for instance the circular field, with the logarithmic potential distribution. With these two calibrations, both easy to do, the errors due to the measuring apparatus become negligible; the main cause of error we could not avoid was the unstable behaviour of the probes.

We used as probes three wires of platinum, mechanically held together, covered with platinum black and treated to eliminate occluded gases.

By this way we could not obtain a stability better than $\pm .1$ (in terms of n; this corresponds to $\pm 2.5\cdot10^{-5}$ of the voltage across the two external probes). However we think that an improvement is possible: we did not have the time to study deeply this side of the problem, but we found that much better results were obtainable with stainless steel, electrolytically covered with copper first, then with platinum black.

Some words about the model: we used a half model in the scale 3:1; two flux surfaces, outside the poles, are represented by two electrical equipotentials (two copper plates, covered with dag, colloidal graphite), to which is applied the supply voltage. The two flux surfaces are obtained by mapping all the field (including the coils) in a smaller scale, using the current field in a thin aluminum foil: we found this system we developed is the most convenient to map 2-dimensional fields with portions where $\mathrm{rot}\,H \neq 0$: the accuracy needed in this mapping is not very high, because the gradient in the useful region below the poles is not sensitive to the precise shape of these surfaces.

We hope in a short time to be able to print a longer paper concerning all these measurements with some of the results.

RIASSUNTO

Viene prensentato un metodo per la misura diretta, in vasca elettrolitica, di una grandezza approssimativamente proporzionale alla derivata seconda del potenziale elettrico. Questo metodo è particolarmente interessante per il rilievo dell'indice di campo n nel traferro di un acceleratore di particelle circolare.