Extended Rose-Shim Design Methods of Laboratory Electromagnets to Generate Highly Uniform Magnetic Field

February, 1990

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In this paper, the Rose-shim design method of laboratory magnets is extended to improve the magnetic field uniformity. Considering the finite dimension of poles, the design chart given by Rose is extended to the case of over compensation design. When the effects of finite dimensions of the pole pieces are considered, the effect of the asymmetry of the poles should be considered first. For this purpose, an analytic expression(Jacobian elliptic function) of the field produced by the semi-infinite rectangular poles is derived using the conformal mapping method. The minute distribution of the magnetic field near the pole gap center is treated, and the explicit expressions for two special cases are derived : pole widths are different and pole axes are displaced with respect to each other. The surface field near the pole edge is calculated, and the effect of the local magnetization saturation on the uniformity is considered. Actual measurements on a magnet with the cylindrical poles showed the extended chart is valid for low field (<0.5T) design.

At high field intensity, the design method based on the conformal mapping becomes invalid due to the local saturation effect. For high field (>2T), an integral method was developed to calculate the magnetic field produced by the conical poles, assuming a uniform distribution of magnetic charge over the pole surface. This method was found valid by measurements made on a magnet with Rose-shim conical poles. The magnet achieved a highly uniform magnetic field at 2.5 T which was used successfully in the polarized target experiment.