

Modifications in the AUTOMESH and other POISSON Group Codes*

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Abstract

In this paper we discuss the improvements in the POISSON Group Codes. These improvements allow one to compute magnetic field to an accuracy of a few parts in 100,000 in quite complicated geometries with a reduced requirements on computational time and computer memory. This can be accomplished mainly by making the mesh dense at some places and sparse at other places. AUTOMESH has been modified so that one can use variable mesh size conveniently and efficiently at a number of places. We will present an example to illustrate these techniques. Several other improvements in the codes AUTOMESH, LATTICE and POISSON will also be discussed.

Introduction

The POISSON Group codes have been developed and written by Holsinger, Halbach and others over a period of several years to design magnets and radio-frequency cavities using the techniques of finite difference equations for solving the Poisson equation^{1,2,3}. These programs require a discretization of the physical geometry of the problem with nonuniform triangles approximating the actual boundaries. The boundaries of the various material and coils can be uniquely defined by a number of points. The program AUTOMESH understands these definitions and produces the other necessary points on the boundary to complete the description. The interior points inside the boundaries are generated by the program LATTICE. The program POISSON finds the solution of the problem for the given geometry by the successive point overrelaxation method.

General Improvements

Although the improvements in the programs are of general nature, we have extensively used them to design and to analyse the superconducting magnets for the SSC (Superconducting Super Collider) and for the CBA (Colliding Beam Accelerator) accelerators. These magnets have fairly complex structures which must be described as accurately as possible, particularly in the coil regions, if the desired accuracy of a few parts in hundred thousand is to be realized in the beam aperture.

These requirements demanded several modifications in the programs. We have modified the AUTOMESH in such a way that one can easily vary the density of nodes (mesh points) at a number of places keeping the total number of nodes constant. Furthermore, certain logical coordinates can be imposed on a particular point to resolve the finer details of the geometry. The above modifications will be discussed in more detail in the next two sections.

The LATTICE part of the POISSON group codes is also modified. This modification was necessary to deal with such a vast change in the mesh density without creating triangles in the physically wrong direction (negative area triangles). These negative area triangles are avoided by

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causing the program to insert a few intermediate points in a region boundary depending on the physical and logical coordinates of the previous and subsequent regions. These new points set the size of the triangles right in the later part of the LATTICE execution. In addition a warning is issued when the user input for a point for its physical and logical coordinates is not consistent with the coordinates of the other points.

The program POISSON has been modified so that there will now be lesser possibilities of a solution to diverge. It is done by controlling the overrelaxation parameter when there appears to be a tendency towards a diverging solution over a large number of iterations. The overrelaxation parameter is optimized from time to time thruout the run to keep the overall rate of convergence high. We have also modified POISSON so that one can have full access to the intermediate results while the original computer run is proceeding for a better convergence. This feature is important because some problems require a very large amount of CPU time and one may like to know the course of run during this period. After analysing the intermediate results one can stop the original run. Conversely, one can recover from the interruption due to computer breakdown etc. and continue the original run from that intermediate place.

Example : A 2-in-1 Super Conducting Dipole

In 2-in-1 magnets, there are two apertures in one iron yoke. Though the structure of the coil is same in the two apertures, the magnitude of the current in the two may be different. Therefore, midplane symmetry should be used to describe this problem. The geometry of the problem above the median plane is shown in Fig 1. To show the coil structure more clearly in Fig 2, we enlarge the coil area by about a factor of sixty and show a quarter of the full coil. Since the reliability of the field in the aperture depends crucially on how accurately the coils are described, all possible details in the coil structure should be incorporated. This requires a sufficiently large number of mesh points in the coil area for two reasons. (1) The circular surfaces of the coils are approximated by a number of line segments. To make a good approximation, the number of line segments, which means, the number of mesh points should be large and (2) to incorporate the small spaces between different coils at various places, the mesh size should be small. We generate a mesh with the above considerations in mind.

New AUTOMESH

The input to the new AUTOMESH is shown in Fig 4. New users may need to consult the User's Guide to POISSON Group codes³ to follow various NAMELIST parameters. Due to limited space, we will discuss only the new NAMELIST parameters. We will also not discuss the improvements other than those reflected in the NAMELIST parameters.

One of the major motivation for improving AUTOMESH was to be able to use variable mesh size efficiently and conveniently. It can be done in any region with the help of new NAMELIST parameters (XSTR,XEND), (KSTR,KEND) and/or (YSTR,YEND), (LSTR,LEND). Here (X,Y) refer to the physical coordinates and (K,L) to the logical. XSTR gets the logical coordinate KSTR and XEND gets KEND. The increment between two consecutive logical coordinates (DX) is $(XEND-XSTR)/(KEND-KSTR)$. A similar concept is adopted for (YSTR,YEND) and (LSTR,LEND). The scale, once so determined, is used in the subsequent regions until it is changed. Any such scale can be stored by

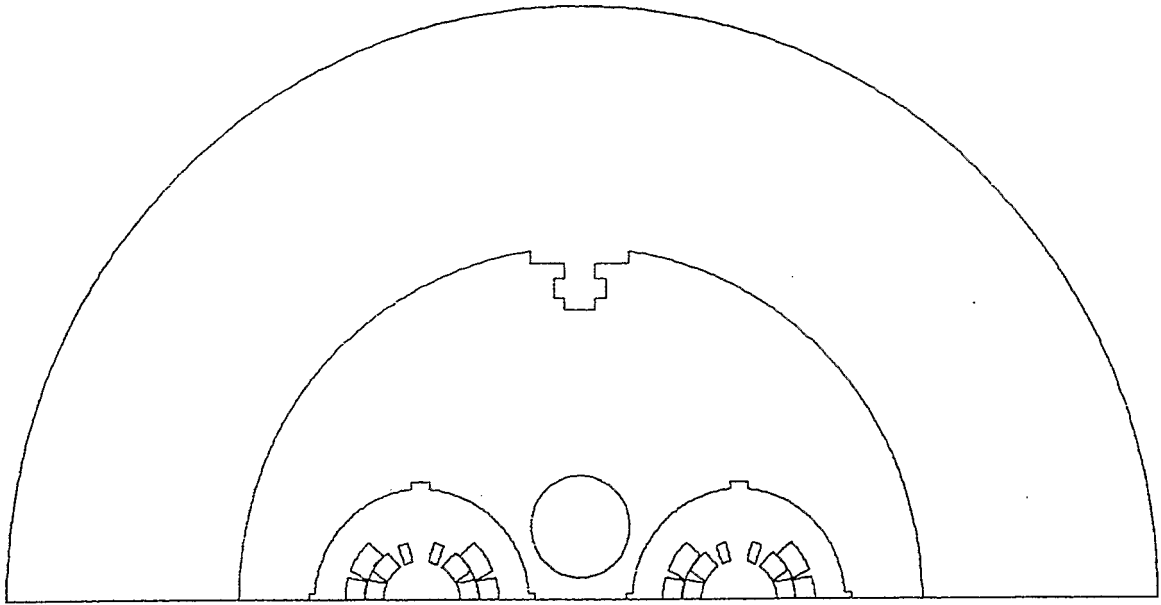


Fig 1. 2-in-1 Magnet above the median plane. We have used this geometry as an example to discuss the improvements.

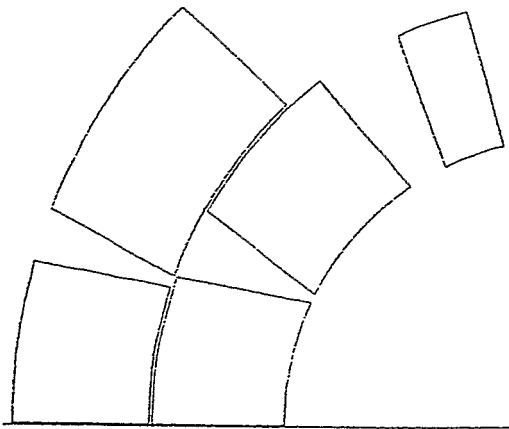


Fig 2. One quarter of the full coil structure. The area of coil in Fig 1 is magnified by a factor of sixty to elaborate the details of the coil structure.

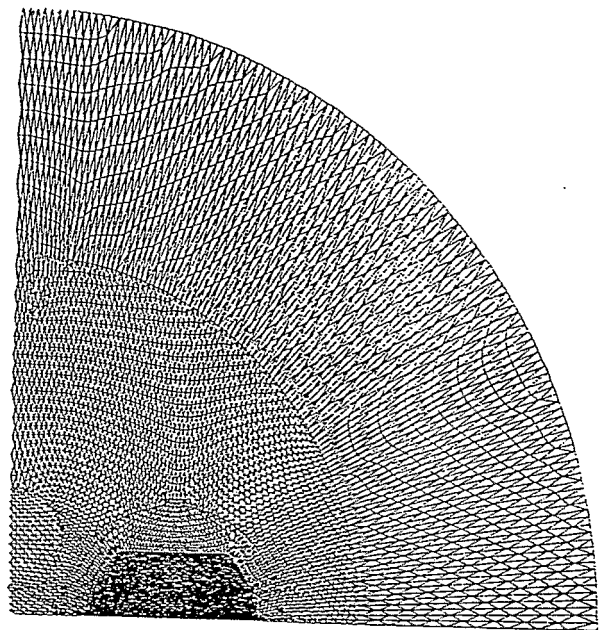


Fig 3. One half of the full mesh generated by modified AUTOMESH and LATTICE programs using the input given in Fig 4.

ICARY=1 NAMELIST parameter. This stored scale may be recalled by simply using ICARY=-1. ICARY=0 (Default) uses the current scale. Sometime it is also desirable to use a different scale within the same region. It is accomplished by breaking a region into a number of contiguous subregions. The NAMELIST parameter ICONT=1 indicates that the next region is in continuation of this region. Once a region is broken into subregions, one can use the techniques described above to use different scales. ICONT=0 signals the end of the continuation. NAMELIST parameter NEXT is used (in the first region) to store the information about the number of such extra regions.

To make a very dense mesh in coil region and lesser dense elsewhere, we use the NAMELIST parameters XSTR, KSTR, etc. Please refer to Fig 1 to Fig 4 for the following discussion. The coils have two layers - inner and outer. The mesh size in the coil region is sufficient to separate different regions (blocks) of coils within the inner and in the outer layers. It was, however, not enough to produce a separation between the two layers and to devise a small midplane gap. To incorporate these details we move the coils by one unit in the logical coordinates. To produce a separation between the two layers, we do the following. In the outer layer we use (XSTR=4.262, XEND=12.248) with (KSTR=94, KEND=144). In the inner layer we use (KSTR=93, KEND=143) for the right side coils and (KSTR=95, KEND=145) for the left side coils for the same (XSTR, XEND). The space created by this shifting of coils (in the logical coordinates) guarantees the separation. To devise a midplane gap, we move the complete coil region up by 1 unit in logical coordinate L. We use LSTR=2 for YSTR=0.0 here as against to LSTR=1 used in earlier regions (IREG=4 and IREG=5) for the same YSTR. The physical space between LSTR=1 and LSTR=2 creates the midplane gap.

In region number 2 we have used (IK=86, IL=58) in the NAMELIST \$PO to override the computed logical coordinates (K,L) for this point. Certain standard rules should be followed in providing the logical coordinates this way. If they are not followed, the program LATTICE will point out the problem at this or at the adjacent point. These new NAMELIST parameters - IK and IL - thus permits one to make final improvements in the mesh. This is particularly useful in resolving the separation between the two regions - say between the lower and the middle block of the inner layer - if the mesh size was not enough to resolve it in the first place. We did not require it here.

As shown in Fig 3, we decided to reduce the mesh size gradually in the regions away from the coils because there the magnetic field is lower and the requirements on the accurate geometry description are less acute. This keeps the number of mesh points and also the computation time low without compromising the reliability of the results in a significant way.

References

1. A. M. Winslow, "Numerical Solution of the Quasilinear Poisson Equation in a Nonuniform Triangular Mesh," J. of Comp. Phys., 2, pp. 149-172 (1967)
2. K. Halbach, "A Program for Inversion of System Analysis and its Application to the Design of Magnets," Proc. 2nd Conf. on Magnet Technology, Oxford, England, July 10th-14th, 1967.
3. R. F. Holsinger, "User's Guide to POISSON Group Codes." The guide for the older version may be obtained from Dr. J.L. Warren, H829, LANL, NM 87545.