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THE ALICE DIPOLE MAGNET

D. Swoboda

Abstract

The design and construction of the ALICE dipole magnet has been co-ordinated within the LEA group. Several teams from collaborating institutes as well as design and engineering resources from CERN participated in the project. The construction of the different main components was entrusted to industry in several countries. The paper highlights some of the major design features and engineering solutions. The requirements for a full preassembly are explained and the assembly procedure as well as the status of the project is summarized.

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1 INTRODUCTION

A large Dipole Magnet is required for the Muon Arm spectrometer of the ALICE experiment in the future LHC.

The magnet is a major part of the ALICE muon spectrometer and provides the bending power to measure the momenta of muons. The aperture and field integral are determined by the requirements on mass resolution and angular acceptance. The absence of constraints of symmetry and homogeneity of the magnetic field has led to a design dominated by economical and feasibility considerations.

The ALICE Collaboration chose a resistive dipole magnet at the meeting in March 1997 and a Preliminary Design Report [1] for the magnet was presented in March 1998. Since then design work has been pursued in JINR/Russia and at CERN [2,3].

The general concept of the dipole magnet is based on a window frame return yoke, fabricated from low carbon steel sheets. The main parameters are summarized in Table 1. In order to maximize the bending power the flat vertical poles follow the required acceptance angle of 9 degrees. The excitation coils are of saddle shape type (Fig. 1).

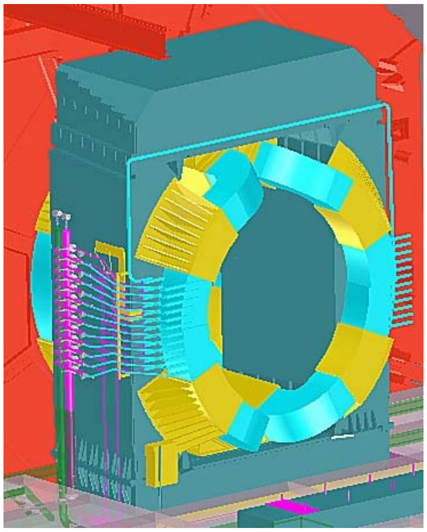

Figure 1: General view of ALICE dipole magnet

The coils are cooled by pressurized demineralized water. The coil ends are located on both sides of the magnet yoke and determine the overall length of the magnet. The main flux direction in the gap is horizontal and perpendicular to the LHC beam axis.

The project is coordinated by CERN. A considerable part of design work has also been carried out by JINR/Russia [4].

Table 1: Main Characteristics of the Magnet

Parameter	Value	Unit
Max Flux density	0.67	T
Bending Strength	3.00	Tm
Avg. Gap width	3.30	m
Ampere turns	1.97	MA
Operating Current	5.86	kA
Coil Voltage	590	V
Power	3.46	MW
Inductance	1.00	H
Diff. Pressure	10.9	Bar
Diff. Temperature	30	°C
Total weight	835	Tons
Overall Dimensions(H x W x L)	9.0 x 6.7 x 5.0	m x m x m

The flux return yoke has been designed and manufactured in Russia. The 28 steel modules of about 30 tons each were machined from laminated, press welded iron blocks, which were recuperated from a former magnet project that had been discontinued.

The two excitation coils are wound from large cross-section hollow high purity Aluminium conductor and vacuum impregnated. Each coil has 12 layers with 14 turns. In order to entrust the manufacturing to industry the manufacturing technology needed to be adapted to the know-how of the selected supplier.

The size of the coil volume requires a rather large amount of resin of more than one ton for each coil. Such quantity is very difficult to manage since the impregnation time during which the epoxy needs to be maintained liquid is several days. Each coil has, therefore, been divided into three sub-coils of four pancakes each. Each sub-coil has been constructed as a self-consistent assembly including ground wrap insulation.

They were manufactured under CERN supervision by French industry. The geometry and size of the coils required the development of special tooling:

A press had to be installed in the winding line to pre-form the insulated conductor at the locations of small bending radii in order to conserve the quadratic conductor cross-section.

Figure 2: Coil shaping tool

The shaping of the coil ends was done on a large cylindrical fixture [Fig. 2]. Hydraulically activated steel cylinders were used to press each pancake into shape. This required precise adjustment of the perimeter of the cylindrical fixture to take spring back of the coil layers into account. Tests have been performed to evaluate this effect [5].

The vacuum impregnation was done in an aluminium mould which was extended for each sub-coil in radial direction using the outer envelope of the previous mould as base for the next sub-coil mould in order to guarantee a good fit of the three sub-coils [Fig. 3].

Figure 3: coil impregnation mould for sub-coil 2

The thermal expansion of the coil will be of the order of 4 to 5 mm during magnet operation. Therefore, the coil will slightly move along the longitudinal supports.

The coils are supported in the yoke with stainless steel support structures which required extensive mechanical and magnetic calculations. These components have been produced in Spain.

Presently all components have been manufactured and delivered to the ALICE experiment site.

In the final location the magnet will be fixed to a steel concrete foundation which is common to the whole ALICE muon detector. This construction is being coordinated by CERN civil engineering group.

To validate the installation procedure and minimize the risk of unforeseen re-machining during final installation, a full assembly and pre-commissioning in a location with convenient access precedes the final assembly in the experimental cavern. This procedure appears essential to verify the conformity of the different components. One of the challenges of the pre-assembly which has started in October 2003 is therefore the correct fitting of the main components.

2 PURPOSE AND BENEFIT OF THE PRE-ASSEMBLY

2.1 Magnet yoke

An assembly in vertical position is necessary to drill all alignment dowel holes and to adjust the shims at the junction of horizontal and vertical modules. The restricted space in the final location where the magnet will be erected on a 3 m high steel concrete platform does not allow any major or precise machining. Removal of parts to be adjusted in surface work shops is equally impractical since all components need to be lifted above the L3 solenoid and then transferred to other cranes.

It is therefore essential to validate the complete assembly procedure in detail prior to the final assembly.

2.2 Excitation coils.

The installation of the two excitation coils is a rather complex and delicate process. The coils are stored and transported in horizontal position. In order to be inserted in the yoke they need to be turned by 90 degree and then lowered into the magnet gap.

The space between yoke and coil ends is just about 10 cm to both sides which requires a perfect control of the operation over the 6 m high vertical yoke modules. In addition both coils are located at a distance of 10 cm with respect to each other in the yoke. The handling jig needs therefore to be designed such as not to extend outside the coil footprint.

2.3 Magnet parameters

In order to verify the proper electrical and magnetic parameters of the dipole magnet it is necessary to test the device at a certain distance from the L3 solenoid or other big metallic masses. The pre-assembly location at the RB 24 side of the ALICE experimental cavern provides this possibility.

The precise calculation of mechanical stresses in the magnet structures [6] is not possible due to the complex configuration involving the two magnets. It is therefore planned to survey the structural stresses in critical locations in order to extrapolate the forces which will occur in the final location close to the L3 solenoid.

2.4 Installation time window

The final installation is tributary to the termination of the installation site and can therefore not be started before August 2004. However, the required time to complete the ALICE detector leaves a very restricted time window for assembly, commissioning and field mapping of the dipole magnet. Consequently, it is compulsory to respect the allocated time. This is only possible with a tested assembly procedure and a pre-installation of all magnet services and control system components. The geometry survey during pre-assembly guarantees also a subsequent correct alignment of the structures.

3 ASSEMBLY PROCEDURE

Two successive assemblies of the magnet are necessary. After the successful first assembly of the yoke and control of overall dimensions, holes for alignment dowels were machined at the interfaces between all yoke modules. For this operation important scaffolding was required for the work at heights of up to 9 m from the foundation level.

The dipole magnet yoke is a self-supporting structure. The yoke base was aligned with shims, i.e. thin steel plates which are inserted between yoke base modules and foundation plate to level each module correctly. Residual alignment tolerances of the vertical modules were corrected by shims of adequate thickness at the mating faces between horizontal beams and uprights.

To allow the insertion of the two excitation coils it is necessary to disassemble the yoke top once the yoke has been fully assembled and commissioned, and to install the lower parts of the coil supports.

The presence of the dowels guarantees the alignment after loosening the bolted connections between vertical modules and yoke base which is necessary to create the play to disengage the yoke top modules.

The coil supports are attached with bolted connections to the yoke. All holes needed to be machined before the insertion of the coils. The lower supports were preinstalled with some tolerance to allow final adjustments once the coils are in place and aligned correctly. The final position of the coil supports is maintained with alignment dowels.

One of the main challenges is the turning of each coil by 90 degree and the subsequent lowering inside the yoke gap. A rather sophisticated handling jig has been designed for this purpose (Fig. 4).

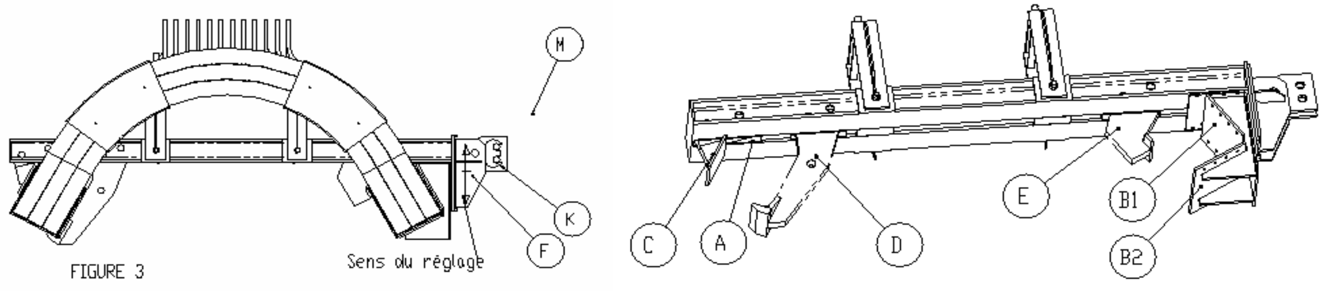

Figure 3: coil installation jig

The main constraints are the very limited space where the coil can be attached and the necessity to be able to extract the handling jig once the coil is positioned in the yoke. Only one overhead crane of 40 ton capacity is available for the operation.

A detailed assembly procedure has been edited. This document was updated with the experience gained during the pre-assembly.

4 CONCLUSIONS

The pre-assembly work has started end of October 2003 [7]. The magnet will be ready for 1st power tests at the end of July 2004. After the pre-commissioning it will be disassembled and installation in the final location will start in December 2004.

The pre-commissioning will include the verification of the overall dimensions of the magnet. All electrical and magnetic parameters will be checked. The temperature profile inside the detector volume will be established in order to check if additional thermal insulation of the dipole coils will be necessary.

Strain gauges will be positioned at the critical junctions between coil supports and magnet yoke. These parameters will be used to detect weak structural elements and eventually provide adequate reinforcements.

The installation planning of the ALICE experiment at point 2 requires a strict and reliable scheduling of the installation. The pre-assembly appears therefore essential to verify the conformity of the different components which are constructed in various locations. The dipole magnet will need to be fully commissioned and the magnetic field map measured within a tight time frame before September 2005.

5 REFERENCES

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