4/9/99

Workshop on the alignment of LHC IR magnets

J. P. Quesnel

1 Introduction

The first aspects of the problem of the alignment of the low beta quadrupoles concern the internal metrology of a cryo-magnet. We implemented studies and tests on the cryo-magnets of the arcs and our experience can be presented

The other aspects of the problem of the alignment concern the positioning itself of the cryostats – and so the magnets - in the tunnel, with the consequences on the targets type, their location…etc.

Based of the experience gained with similar studies made on the magnets of the arcs, a method for combining the individual errors or tolerances is proposed.

2 Tolerances, what does it means ?

To avoid any confusion when speaking of tolerances, accuracy, precision, and when combining several values together, we have adopted a simple rule based on the statistic laws.

First, each individual error is identified, and only the r.m.s. value of this error is considered. That means that we have 66% chance to reach this value, in a gaussian repartition. So at this level, we don't speak of tolerance. It is only the quadratic sum of all the individual errors which can gives us the final precision (r.m.s.) of a process. The tolerance is three times this value.

3 Mechanical aspects

Our contribution on this point can mainly be to explain what measurements are done at CERN for the magnets of the arcs.

3.1 Stability of the cold mass w.r.t. the cryostat

Measurements have been made on the main dipoles and on one straight section of the arcs. The monitoring is made by the mean of two capacitive sensors which control the position of two targets. These controls can be made during magnetic tests, at cold and warm temperature.

Because of the interference of the targets with a blocking system of the cold posts during transportation, it is not possible to use this device to evaluate any movement of the cold mass during the transportation of the cryo-magnets. In the way to measure the displacements of the cold mass during transportation, measurements are made at the ends of the cryo-magnets using a photogrametric method.

3.2 Stability of the shape of the cryostat

Two different layouts for the position of the external supports of the cryostats have been studied and tested on a 15 meters long cryo-dipole. These tests have shown that the shape of the cryostat could be affected by a variation of temperature between the top and the bottom of the cryostat. Theoretical studies (finite elements) on the shape of the cryostat (ovalisation, thermal effects, longitudinal tilt….etc) have been proceeded and new tests are scheduled to confirm the conclusions.

These conclusions could have an impact on the number of supports , and consequently on the number of alignment targets to be installed on the cryostat.

4 Positioning in the tunnel

4.1 The global network

The geodetic network which will be used in this area is described.

To increase the chance to obtain a good positioning of the low beta quadrupoles in these areas, CERN has decided to built galleries dedicated to the transfer the geometry from one side of the experience to the other side, around ATLAS and CMS. Such galleries will not be built around ALICE and LHC-β For these two

points the left to right geometry will be measured after the dismantling of the actual LEP experiments, and kept up to date with a dense network fixed on the floor of the tunnel. The relatively small ground motion expected due to no civil engineering activity in these areas justifies this decision.
The network fixed on the floor is to be used up to the first installation of the magnets, when the tunnel is empty, and is determined with measurements made from the LEP quadrupoles. After the first alignment of the magnets, the reference points of the geodetic network are the alignment targets themselves and the floor points are not be used anymore. This method allows the most accurate relative alignment of the elements together.

4.2 The alignment targets

These targets are the image of the cold masses outside the cryostat and allow the positioning, as the magnetic axis of the magnets is not accessible. The number and the localisation of these targets depend strongly on the "rigidity" of the objects to be aligned, on the number of external jacks which support the objects, and the different operations to be done for the positioning, as well as the topology of the tunnel.
Based on the hypothesis where the cryostats are rigid, only 3 alignment targets per cryostat are needed. They have to be located longitudinally as close as possible as possible to the sections containing the 3 jacks. The position of these targets have to be known w.r.t. to the magnetic axis of the cold mass. These targets are used for the positioning of the cryostat w.r.t. the machine, the experiment and the other magnets. They have to be located as close as possible to the reinforced part of the cryostat, for stability reasons.

4.3 The stability control points

Because of the high accuracy requested on the positioning of the magnets, each cryostat will have to be equipped with 3 additional control points, two for the control in X, Y and Z, one for Z. Sensors able to detect any movement of a cryostat w.r.t. the two others of the inner triplet will be installed on these points. These control points have to be located close to the alignment targets, but should be different, to avoid any dismantling of the stability control equipment when re-aligning the magnets annually.
All these points – alignment targets and stability control points - are also used as points of. the geodetic reference network and will help us to link the geometry between the two sides of the experience. They also have to be known accurately w.r.t. the magnetic axis.
For standardisation reasons, the alignment targets and the stability control points are of the same type adopted for the LHC components.

4.4 The equipment to be used for the measurements

A method based on hydrostatic levelling is planed to be used for the link between the two sides of the experience in the vertical direction (Z), as well as for the vertical stability control of each cryomagnet (in Z and in the transversal tilt).
A wire will be stretched through the survey galleries and across the experimental cavern to link the two sides of the experience in the radial direction, and another wire will be stretched along each inner triplet up to the D1 magnet to allow the radial control of the stability of each triplet as well as to link this area to the rest of the machine.
All these equipment are planed to be installed permanently.