EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN – ACCELERATOR AND TECHNOLOGY SECTOR

CERN-ATS-2011-081

VALIDATION OF A MICROMETRIC REMOTELY CONTROLLED PRE-ALIGNMENT SYSTEM FOR THE CLIC LINEAR COLLIDER USING A TEST SETUP (MOCK-UP) WITH 5 DEGREES OF FREEDOM

H. Mainaud Durand, M. Anastasopoulos, S. Griffet, J. Kemppinen, R. Leuxe, M. Sosin,
CERN, Geneva, Switzerland

Abstract

The CLIC main beam quadrupoles need to be pre-aligned within 17 μm rms with respect to a straight reference line along a sliding window of 200 m. A re-adjustment system based on eccentric cam movers, which will provide stiffness to the support assembly, is being studied. The cam movers were qualified on 1 degree of freedom (DOF) test setup, where a repeatability of adjustment below 1μm was measured along their whole range. This paper presents the 5 DOF mock-up, built for the validation of the eccentric cam movers, as well as the first tests carried out: resolution of displacement along the whole range, measurements of the support Eigenfrequencies.

VALIDATION OF A MICROMETRIC REMOTELY CONTROLLED PRE-ALIGNMENT SYSTEM FOR THE CLIC LINEAR COLLIDER USING A TEST SETUP (MOCK-UP) WITH 5 DEGREES OF FREEDOM

H. Mainaud Durand, M. Anastasopoulos, S. Griffet, J. Kemppinen, R. Leuxe, M. Sosin , CERN, Geneva, Switzerland

Abstract

The CLIC main beam quadrupoles need to be pre-aligned within 17 μm rms with respect to a straight reference line along a sliding window of 200 m. A re-adjustment system based on eccentric cam movers, which will provide stiffness to the support assembly, is being studied. The cam movers were qualified on 1 degree of freedom (DOF) test setup, where a repeatability of adjustment below 1μm was measured along their whole range. This paper presents the 5 DOF mock-up, built for the validation of the eccentric cam movers, as well as the first tests carried out: resolution of displacement along the whole range, measurements of the support Eigenfrequencies.

INTRODUCTION

In order to limit emittance growth and implement beam based alignment and beam based feedbacks, more than 4000 Main Beam (MB) quadrupoles will have to be pre-aligned within 17 μm rms with respect to a straight line along a sliding window of 200m over the whole length of the CLIC linacs. Because of the tight tolerances of pre-alignment, taking into account the number of components concerned and environment conditions (variation of temperatures, radiation fluencies), this pre-aligment will be active: sensors coupled to the quadrupoles will be used to compute the position of the quadrupoles and the adjustment will be performed by movers supporting the quadrupoles through an iterative process. The solution for adjustment has to be compatible with the stabilization requirements concerning each quadrupole: 1.5 nm integrated rms displacement at 1 Hz. Eccentric cam movers that should bring stiffness to the whole assembly are proposed. Cam movers were first validated individually on a 1 DOF test setup, where a repeatability of adjustment below 1 μm was demonstrated. The next step of the study is their validation on a 6 DOF test setup mock-up, with all degrees motorized (horizontal, vertical displacements, pitch, yaw, roll (rotations around horizontal, vertical and longitudinal axis)), except longitudinal one. In this paper, the general concept of active pre-alignment using cam movers is detailed, as well as the results of the first tests carried out.

ACTIVE PRE-ALIGNMENT USING CAM MOVERS

Active pre-alignment

The pre-alignment takes place before the first pilot beam is sent, when there is no beam. According to the stability in the tunnel floor, it could take place every 2-3 days, once the alignment of components is no longer compatible with the requirements. If micrometric displacements are needed when beam is on, this will be carried out by stabilization devices or dipole corrector installed at one extremity of MB quadrupole.

Determination of the position

The position of each MB quadrupole will be given by 2 WPS (performing radial and vertical offserts measurements with respect to a stretched wire within a micrometric precision and accuracy) and 1 biaxial inclinometer located on the support. Prior to that, a fiducialisation of the MB quadrupole and Beam Position Monitor (BPM) will have been performed. The fiducialisation takes place before the installation of the components on a common support; it allows the determination of the reference axis of each component with respect to external fiducials. Then the two components are assembled on a common support. During that stage, the position of the sensors interfaces located on the support is determined at a micron level thanks to 3D Coordinate Measuring Machine (CMM) with respect to the fiducials of each component, provided a given position of stabilization system linking the support to the MB quadrupole.

The position of the reference axis of MB quadrupole and associated BPM will be determined according to the readings of WPS sensors w.r.t alignment reference (Support Pre-alignment Network). The alignment reference will consist of stretched wires with a length of 200 m, overlapping over half their length (Metrologic Reference Network) [1].

Requirements for re-adjustment

The requirements concerning re-adjustment are the following:

- A repeatability of 1μm
- A stroke of ± 3 mm
- Speed > 0.01 mm/s

- First resonance of the common support located above the adjustment system > 50Hz
- Total load applied on the re-adjusment system: ranging from 100 kg to 300 kg, according to the length of MB quadrupole assembly (0.5 m to 2m)

Configuration of cam movers

After a study of several possible solutions (linear actuators, wedge system), eccentric cam movers were chosen as a solution for re-adjustment of MB quadrupole support, with the following configuration:

- 5 cam movers in order to provide 5 DOF,
- A kinematic mount interface below the common support of MB quadrupole, providing a unique solution of interface via a conical chamfer, a flat plane and a conical hole
- 4 interfaces with ground for higher stiffness

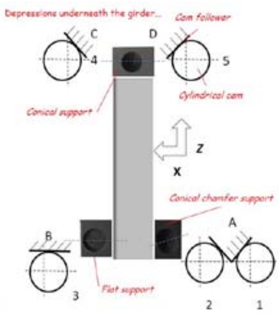

Figure 1: Configuration of cam movers

Study on 1 DOF test setup

Validation of these movers started with tests carried out on a 1 DOF test setup on upgraded SLS cam movers [2]. Three different combinations of bearing and bearing ring installed around the eccentric cam shaft in cam mover were compared through repeatability tests. In all cases, the repeatability was well below micron.

After these very positive first results, it was decided to validate cam movers on a 5 DOF setup. As 1 DOF tests did not show significant difference between the three different types of bearings, the 5 DOF tests will be repeated using a second set of bearings which are of different type than the first set.

5 DOF SETUP (MOCK-UP)

Description

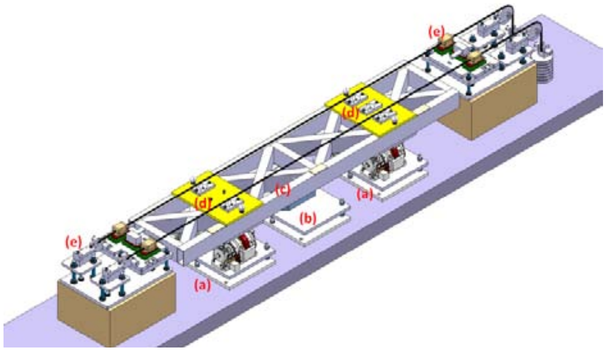

Figure 2: Description of 5 DOF setup

The 5 DOF setup consists of the following parts:

- Two mechanical plates (a) providing a manual pre-alignment along 6 DOF within 0.1 mm precision and accuracy of the cam movers with respect to ground settlement (range of displacements of a few millimetres). Once first measurements of Eigenfrequencies on the support have been carried out, concrete will be added all around and between the plates in order to increase the stiffness of their assembly. Cam movers are mounted on the upper plates.
- One device (b) performing manual longitudinal adjustment of the support
- The support (c) itself designed specifically for the setup, with a deformation under self weight in the center below 1µm, and 5 sensors interfaces (d) (4 interfaces for WPS sensors and for 1 biaxial inclinometer), providing redundancy of measurements in all degrees of freedom.
- 4 additional targets for 1.5” CCR prisms allowing measurements with Faro arm and laser trackers as well as 5 reference planes.
- In order to provide a reference of position while the support is displaced with the cam movers, reference sensors (e) have been added on each side of the support, installed on concrete block.

The position of the sensors interface, of the additional targets, as well as the cam movers interfaces were measured on 3D CMM with a tolerance of 6 µm.

Two configurations of loads (300 kg) have been designed depending on the objectives of the test setup: a first one more rigid, with a center of mass corresponding to that foreseen for the measurements of Eigenfrequencies, a second one more simple and less rigid allowing the crossing of the stretched wires.

Status

A first blank assembly of the whole mock-up has been built, in order to check the strategy of installation. Some first Eigenfrequencies measurements were carried out before adding concrete around the mechanical plates.

Some first tests of displacements were also achieved. See later chapter on results.

Figure 3: Blank assembly of 5 DOF setup

CAM MOVERS

Description

New cam movers designed by the firm ZTS vvu Kosice had the following improvements compared to the upgraded SLS cam movers [3]:

- A more rigid structure
- Smaller clearances between parts
- Higher gear ratio (Worm gearbox ratio = 60, bearing reducer ratio = 85)
- Different worm gear and stepper motor
- The stepper motor and the worm gear unit are coupled to the cam shaft via a zero backlash bearing reducer instead of a planetary gear
- A high resolution absolute rotary angle encoder from Renishaw is directly mounted on the cam shaft

The eccentricity of 5 mm was maintained.

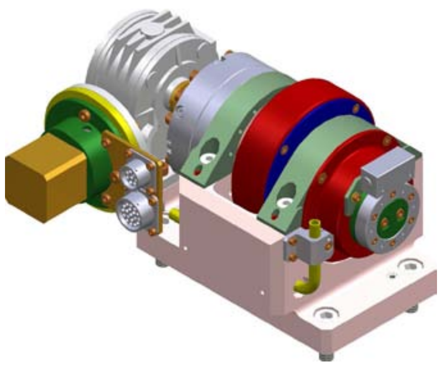

Figure 4: 3D model of cam mover

1 DOF mock-up results

5 cam movers were ordered for the 5 DOF setup. In addition, the manufacturer made one spare cam mover. The spare mover was tested in the 1 DOF mock-up.

Repeatability within the whole range of +/- 5 mm was below 1 µm and below 0.3 µm when a reduced stroke of +/- 3mm was used.

The cam mover has approximately 20 µm of hysteresis. It is constant so its effect can be eliminated in 5 DOF control algorithms.

LATEST RESULTS

Resolution measurements

According to the manufacturer, the cam mover’s movement resolution is 3.8 arcseconds. Based on this, the 5 DOF setup’s theoretical resolution in translations (only sway and heave motions possible) is below 1 µm and in rotations below 1 µrad.

The cam movers were not calibrated before the blank assembly of the 5 DOF setup so the control algorithm cannot be fully exploited. Therefore it was not possible to test the resolution of re-adjustment of all translations and rotations separately.

First tests do however indicate that the re-adjustment resolution of sway and heave are below 2 µm. The facility where the setup was assembled is so noisy that the standard deviation of the WPS sensors is approximately 1.3 µm. For this reason, translations that are smaller than 2 µm cannot be reliably tested.

Eigenfrequencies measurements

Some preliminary measurements of the resonant frequencies of the support were performed, before concrete is added in order to rigidify the mechanical plates [4]. Several natural frequencies were measured and identified at 16 Hz, 27 Hz, 41 Hz, 45 Hz. They came from the mechanical plates and their anchoring screws, not optimized for such a configuration without concrete. Therefore, it was not possible to distinguish among these frequencies the resonant frequency of the support itself.

Near the test setup, a RMS integrated level close to 9 nm at 1 Hz was computed; this confirmed that the area is too noisy for micrometric measurements.

CONCLUSION

The 5 DOF mock-up designed to qualify cam movers for micrometric adjustment during the pre-alignment phase is now in place after a “blank assembly”, and has brought its first results indicating that the re-adjustment resolution of sway and heave is below 2 µm.

Next step will be first the dismounting of the mock-up in order to perform the individual calibration of each cam mover. At the same time, the mechanical plates will be concreted. Second, after remounting of the mock-up, the measurements of Eigenfrequencies will take place. Third, all the tests dealing with the qualification of cam movers will be carried out: check of available range, repeatilibity and resolution of displacements along this range, validation of the algorithm of re-adjustment.

REFERENCES

[1] H. Mainaud Durand *et al.*, "CLIC active alignment system: proposal for CDR and program for TDR", IWAA 2010, DESY, 2010

[2] J. Kemppinen *et al.*, "Validation of CLIC re-adjustment system based on eccentric cam movers – one degree of freedom mock-up", Measurement 2011, Smolenice Castle, Slovakia, 2011

[3] D. Cani, "Eccentric cam movers software description", technical note, ZTS vvu Kosice, July 2010.

[4] R. Moron Ballester, "Experimental modal analysis of a CLIC girder", EN-MME mechanical measurements Lab report, edms n°1152988, CERN, 2011.