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MOTORIZED UNIVERSAL ADJUSTMENT PLATFORM FOR MICROMETRIC ADJUSTMENT OF ACCELERATOR COMPONENTS

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Abstract

In order to optimize alignment activities in a highly radioactive environment, the Geodetic Metrology Group at CERN has developed a standardized featuring 6 degree of freedom (DoF) Universal Adjustment Platform (UAP). After a first prototyping phase in 2021 with a manual UAP, the design has been consolidated and is now compatible with the installation of motorized actuators to form a remotely adjustable 5-6 DoF platform able to perform positioning with micrometre resolution. This paper presents the UAP and related motorized actuator development, elaborated in the frame of the High-Luminosity Large Hadron Collider project. The mechanical integration approach, design solutions, and test results are discussed.

INTRODUCTION

The CERN Large Hadron Collider (LHC) accelerator will soon be upgraded to operate at five times higher nominal luminosity to increase its potential for discoveries after 2029. In the frame of this project, named High-Luminosity-LHC (HL-LHC), nearly 1.2 km of beam components will be replaced [1, 2]. One of the key parameters to increase the integrated luminosity is the precise alignment of the accelerator components of the two high luminosity experiments in the Long Straight Sections (LSS). For the first time, a Full Remote Alignment System (FRAS), composed of a set of micrometre sensors and actuators, will be implemented on the HL-LHC components to determine continuously the position of the components and re-adjust them remotely if needed [3].

In the frame of this project, a Universal Alignment Platform (UAP), able to adjust lightweight accelerator components (up to 2000 kg) within 6 Degrees Of Freedom (DoF), has been developed by the Geodetic Metrology Group at CERN. This platform is an adaptive framework that will be used for several accelerator components such as collimators. It is based on in-house designed components, that can be scaled to the accelerator component according to its supporting points, available volume, etc. The concept of such a platform has been already presented in [4]. This paper focuses on the platform components characterization and details the proposed motorisation solution to perform remote adjustments in the frame of FRAS.

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6 DOF PLATFORM CONCEPT

The UAP platform is composed of the following elements (Figure 1):

- A lower interface plate (Blue) that is considered as fixed.
- A set of 6 micrometre actuators (Red) to perform adjustments in all DoF. The radial actuation is carried out by radial jigs while the vertical and longitudinal adjustments are performed by vertical jigs.
- Backlash-free joints (grey), with tailored length to remove any hyperstatism.
- A set of actuating shafts and supports (Orange), gathered at the front part of the platform for an easy access during the actuation of each jig.
- An upper plate (green) on which the accelerator component can be installed.

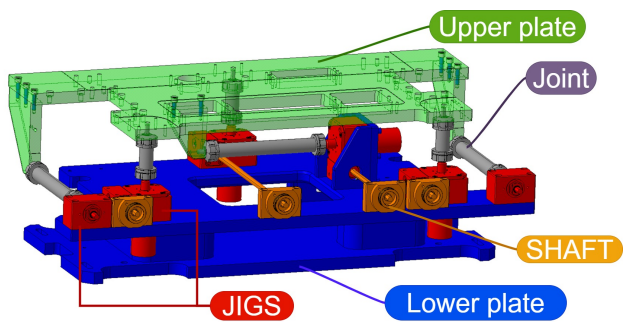

Figure 1: UAP Platform Composition.

Jigs, Joints and actuation shaft designs are now internally available at CERN and each user adapts the upper and lower plate to his needs. All these components are proposed for two models: a Light platform version (Safe Working Load - SWL- up to 300 kg) and a Heavy one (SWL up to 2000 kg). The application of this framework guarantees a common alignment procedure for all lightweight elements regardless the specificity of the supported component design. The first application has been developed in collaboration with the collimator team at CERN to validate the concept via 2 prototyping phases and obtain a robust design before serial production.

Based on this manual design, the paper presents the different steps of design and tests phases towards a motorized version compatible with the FRAS project.

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INDIVIDUAL JIGS CHARACTERISATION

In order to obtain a preliminary estimation of the global behaviour of the platform , the mechanical parameters of a set of jigs (both radial and vertical) have been fully verified and characterised. This characterisation has been based on a sampling production corresponding to 3 complete UAP platforms. For each jig, the following parameters have been recorded for several positions distributed along the total jigs strokes (see Table 1):

- Maximal actuation torque over the full stroke without load on the output piston to check the smoothness of the actuation.
- 150 % Load test to check the structural viability of each jig with a monitoring of the necessary input torque.
- Input Jig Backlash - it represents the necessary rotation on the input shaft of a jig to get a detectable output motion (2 µm). The result is computed as a position defect on the output piston.
- Output Jig Backlash - it represents the output piston motion stroke when experiencing an alternated load of ±10 kg.

In order to record all these characteristics, a specific qualification bench coupled with an acquisition software has been designed to automatise most of the qualification steps and gather reliable results (see Figure 2). This bench will be used later to qualify the serial production and detect as soon as possible any potential manufacturing defects.

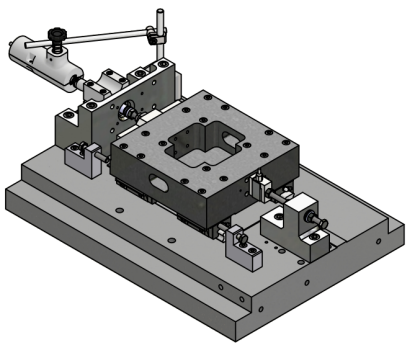

Figure 2: UAP Jig test bench overview.

Table 1: Mechanical Parameters - Vertical Jig

PARAMETER	TARGET	RESULT
Unloaded torque [N m]	<0.5	0.37
150 % Load torque [N m]	<8	6.7
Input Backlash [µm]	<15	13.3
Output Backlash [µm]	<5	3.4

MANUAL PLATFORM PERFORMANCES

Once the individual jigs were characterised, three complete UAP platforms have been assembled to support a set of three collimators. A series of tests, aiming to represent the different use-cases of the platform, have been conducted in a manual way before installing the motorized adapters (see Figure 3):

- Stability of the platform under external perturbation load : the platform position remains stable (< 20 µm displacement) when external forces of up to 100 kg are applied to the structure and then removed.
- Global stiffness behaviour - maximal displacements when 20 kg are applied longitudinally and radially to the structure are 240 µm along the Beam axis direction and 120 µm along the traversal axis.
- Single DoF adjustment - conducted to characterise the impact of one jig actuation on the other movements (parasitic motion of the platform).
- Position repeatability test : when the structure payload is removed and reinstalled, the payload position has been validated as repeatable (12 µm translation and 10 µrad rotation defect recorded)
- 3D Alignment - for a defect up to 10 mm, the alignment sequence requires only 3 iterations to reach an adjustment position scope of ±50 µm translation and ±100 µrad rotation.

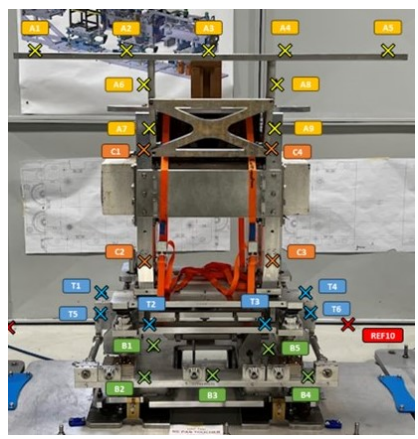

Figure 3: UAP Platform during test with a dummy collimator. Each cross represents a measurement target installed during the tests.

MOTORISED ADAPTERS CHARACTERISTICS AND IMPLEMENTATION

In order to be compatible with the FRAS, a motorized version of the UAP platform is necessary. The proposed concept, compatible with the standardisation philosophy of the UAP, is to develop a plug-in micrometre motorised adapter able to be connected directly to the manual version of the platform (Figure 4).

Based on the concept presented in [5] and the prototypes tested for the actuation of other equipment (see Figure 5), the design of two motorised adapters, dedicated to radial and vertical jigs, is currently in progress. These Micrometre resolution motorized adapters will be used to remotely actu-

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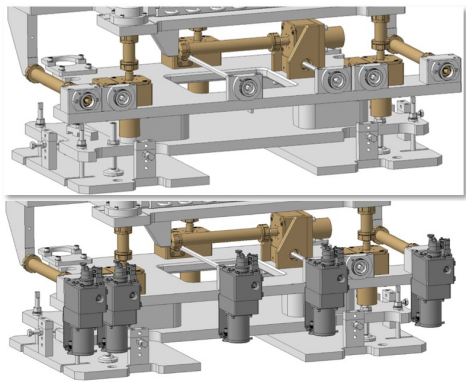

Figure 4: UAP Platform in manual and motorized versions.

ate the UAP platform. These actuators main characteristics are the following:

- Motorized actuation stroke at the jig level of ±2.5 mm.
- Possible readjustment of the motorized stroke within the JIG global stroke of ±15 mm.
- Absolute position monitoring at a micrometre level (20 µm maximal defect along the full stroke), provided by an embedded resolver in the adapter.
- Mechanical end-stop safety feature in order to prevent any displacement above the allowed stroke.

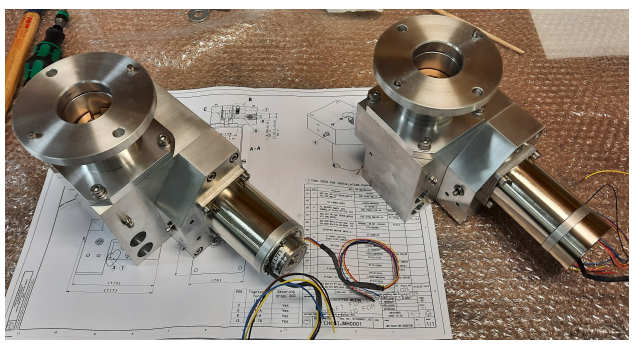

Figure 5: Motorized adapter overview.

Because vertical and radial jigs do not have the same gear ratio, an output stroke of ±2.5 mm on both jigs will represent, at the level of the actuator, a global stroke of 5 rev and 18.75 rev respectively for the radial and vertical adapters. Two different models of the same adapter design will then be provided in order to cope with the specificity of each type of jig.

CONCLUSION

In order to ease the design of a micrometre adjustment platform and to cope with the requirements of the FRAS Project, the Geodetic Metrology group at CERN, in close collaboration with UAP users, designed and tested the Universal Adjustment Platform and its standardized components. After two prototyping phases, the platform and its jigs are now fully successfully qualified and have been presented in this document.

The motorisation design of the platform is being finalized. It is based on already developed motorized adapters [5], allowing the remote and micrometre adjustment of the position of each jig. These adapters will be used as a plugin system able to transform a fully manual platform in a motorized version.

REFERENCES

[1] G. Apollinari, I. B. Alonso, O. Brüning, M. Lamont, and L. Rossi, "High-Luminosity Large Hadron Collider (HL-LHC): Preliminary Design Report", CERN, Geneva, Rep. CERN-2015-005, 2015. doi:10.5170/CERN-2015-005

[2] O. Aberle *et al.*, "High-luminosity large hadron collider (HL-LHC): Technical design report", CERN, Geneva, Rep. CERN-2020-010, 2020. doi:10.23731/CYRM-2020-0010

[3] A. Herty *et al.*, "HL-LHC Full Remote Alignment Study", in *Proc. IPAC'19*, Melbourne, Australia, May 2019, pp. 3716–3719. doi:10.18429/JACoW-IPAC2019-THPGW057

[4] M. Sosin, T. Blaszczyk, A. Herty, J. Jaros, and H. M. Durand, "Design and Study of a 6 Degree-Of-Freedom Universal Adjustment Platform for HL-LHC Components", in *Proc. IPAC'19*, Melbourne, Australia, May 2019, pp. 3720–3722. doi:10.18429/JACoW-IPAC2019-THPGW058

[5] M. Noir, M. Sosin, B. Piotr, and J. Wojciech, "Development and Qualification of Micrometric Resolution Motorized Actuators for the High Luminosity Large Hadron Collider Full Remote Alignment System", presented at MEDSI'23, Beijing, China, 2023, paper THOAM01, this conference.