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Qualification and tests on Universal Adjustment Platform to position accelerator components

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Abstract

In the framework of the High-Luminosity-LHC (HL-LHC) project at CERN, a Universal Adjustment Platform (UAP) has been developed to position accelerator components with a weight below 2 tonnes, according to 5 or 6 degrees of freedom. The target is to achieve a displacement resolution of each axis better than 10 µm. The objective of developing such a UAP is to unify the design process, simplify the adjustment activities and minimize the time required to align the components installed in high radiation areas. To validate the performance of the designed platform, a UAP prototype was built. During the qualification tests, its manual alignment performance with a real accelerator component was verified, before equipping it with motors and sensors, towards a completely automatic adjustment process. This paper focuses on the qualification tests performed on the manual UAP platform.

Universal Adjustment Platform

1. Introduction

The objective of the High-Luminosity-LHC (HL-LHC) project at CERN is to increase the integrated luminosity of the Large Hadron Collider by a factor of 10 with respect to its original design. Reaching such a machine performance requires the replacement of more than 1.2 km of accelerator components in the Long Straight Sections (LSS) around the ATLAS and CMS detectors [1, 2].

The alignment of HL-LHC LSS components will be provided by the Full Remote Alignment System (FRAS) adopted for the HL-LHC baseline, which consists of several elements allowing the remote monitoring and adjustment of accelerator components [3]. One of the adjustment equipment is the Universal Adjustment Platform (UAP), proposed to ease the adjustment of the lighter components of the LSS, mainly collimators, small masks and beam instrumentation devices. The UAP has been designed as a standardized and scalable solution, allowing both for a motorized and manual operation [4].

The design and tests of the UAP have started at CERN in 2018, with satisfactory results for the small platform prototype for component weights < 300 kg [5]. The success of the tests on the small UAP allowed to design the large UAP version in 2020, dedicated to heavier equipment ranging from 300 kg to 2000 kg). This large UAP design was targeted to HL-LHC collimators; the corresponding qualification tests are described hereafter.

2. Large Universal Adjustment Platform qualification test

The UAP has been tested with a collimator installed on it (Fig. 1). Seven points have been placed on the floor around the UAP in order to construct a stable, external reference network (cf. Fig. 1, blue 'REFn'). Five points have been installed on the bottom plate of the UAP (green 'Bn') and 5 points on the top plates (red, 'Tn') in order to follow the movement of the platform with respect to the network. The position of the collimator is deduced from 9 points referenced to the beam axis of the element (yellow, 'Cn'). The measurements have been performed with a laser tracker (Leica AT401) to ensure on each point a position measurement accuracy better than 15 µm(1σ).

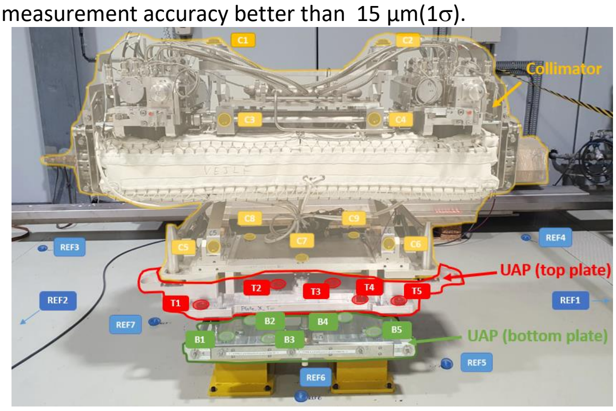

Figure 1. UAP test setup loaded with a collimator (approx. 500 kg)

3. Long-term stability

Two long-term stability tests have been performed in two different positions of the UAP, each one for a period of 15 days. The first stage involved measuring the stability of the collimator with respect to the reference points with a platform adjusted horizontally (the force vector of the collimator is perpendicular to the plane of the UAP). No movement has been observed between the platform and the collimator.

The second stage was to test the long-term stability of the setup with a collimator installed to the maximum roll allowed by the platform (33 mrad). After 15days, no movement has been observed between the platform and the collimator.

4. Stability with external disturbing and reaction forces

Once installed in the accelerator, the components can be subjected to external forces such as human handling activities. The aim of this test was to control the stability of the element after a random disturbance caused by a shock. The position of the collimator has been measured before and after being disturbed. The component was shaken with 500 N force, assumed as an equivalent of pulling (disturbing) force caused by human. The test has been performed in different positions of the UAP. No movement has been observed with the platform set horizontal. Some movements up to 50 µm have been observed on the collimator with a platform tilted to the maximum roll.

The components are also subjected to external reaction forces, transmitted through the flexible connection bellows from adjacent components. The stability of the collimator has been checked with an external force of 200 N applied at the level of the bellows. This value was assumed as maximum lateral, elastic reaction force expected at the bellows level. For a longitudinal force of 200 N (along the Y axis), some temporary movements up to 80 µm have been observed along the beam axis.

5. Ergonomics

The objective of developing the UAP is to unify the design process, simplify the adjustment activities, and minimize the time required to align the components installed in areas of high ambient dose rate, hence the adjustment ergonomics is an essential factor. In order to verify the UAP ergonomics, two tests have been performed. The first part consisted of testing independently the 5 degrees of freedom. Tables 1 and 2 show the behavior of the UAP. The movement objectives and actions on the knobs have been set for each degree of freedom. For the translation movements (cf. Table 1), no parasitic movement has been observed on the other degrees of freedom. For the rotation movements (cf. Table 2), the parasitic movements observed at the level of the collimator were derived from the kinematics of a UAP and could be anticipated in operation.

Table 1. Translation test

		Radial movement	*Vertical movement*
Objective		**1.00 mm**	**1.00 mm**
Actions on the knobs	*Knob 1*	*+ 1 turn*	
	Knob 2		*+3 turns*
	Knob 3		*+3 turns*
	Knob 4		*+3 turns*
	Knob 5	*+1 turn*	
Observations on the Degrees Of Freedom at the level of the collimator	Tx	**1.00 mm**	--
	Ty	--	--
	Tz	--	**1.00 mm**
	Rx	--	--
	Ry	0.02 mrad	--
	Rz	--	0.02 mrad
Parasitic movement		No	No

Table 2. Rotation test

		Pitch rotation	*Roll rotation*	*Yaw rotation*
Objective		**3.90 mrad**	**5.40 mrad**	**2.60 mrad**
Actions on the knobs	*Knob 1*			*+1 turn*
	Knob 2	*+3 turns*	*+3 turns*	
	Knob 3		*- 3 turns*	
	Knob 4	*-3 turns*	*+3 turns*	
	Knob 5			*-1 turn*
Observations on the Degrees Of Freedom at the level of the collimator	Tx	--	1.3 mm	--
	Ty	0.6 mm	--	--
	Tz	--	0.1 mm	--
	Rx	**3.90 mrad**	--	0.02 mrad
	Ry	--	**5.40 mrad**	0.02 mrad
	Rz	0.05 mrad	--	**2.60 mrad**
Parasitic movement		Longitudinal when pitch adjusted	Radial when roll adjusted	No

The aim of the second test was to verify the UAP ergonomics by a practical adjustment test. A virtual, nominal axis has been defined with respect to the floor (cf. Fig. 2). The objective was to manually adjust the UAP in a way to match the collimator axis with the nominal axis to better than 50 µm.

At the initial position, the collimator axis was misaligned up to 3.8 mm from the nominal axis. A simplified kinematic model has been established to calculate the number of turns of each knob needed to position the collimatior on the nominal axis. After the first iteration, the position of the collimator axis was converging towards its objective. A second iteration has been performed in order to achieve the nominal position within 20 µm (well within the objective).

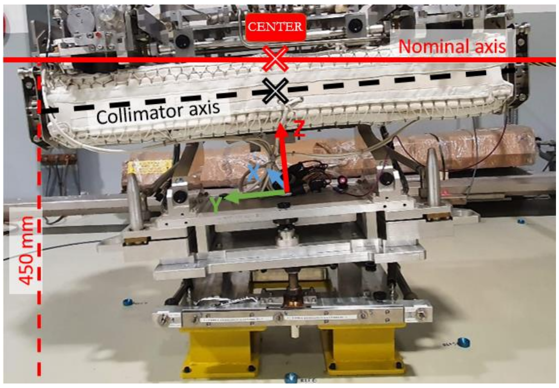

Figure 2. UAP at one of extremity positions

Table 3. Rotation test

	Tx mm	*Ty mm*	*Tz mm*	*Rx mrad*	*Ry mrad*	*Rz mrad*
Misaligned position	**3.166**	**0.276**	**3.832**	2.276	3.813	2.660
Alignment 1st iteration	**0.065**	**0.043**	**0.076**	0.279	0.128	0.223
Alignment 2nd iteration	**0.011**	**0.002**	**0.017**	0.020	0.056	0.061

The time required to fulfil the alignment within 50 µm (objective) was less than 15 minutes and could be even optimized by having a better integration of measurement software and the kinematic model tool (spreadsheet, software tool) used by surveyors.

6. Conclusions

The qualification tests of the large UAP demonstrated a very good performance of the platform and its immunity to external disturbing forces. The UAP is stable within the required 50 µm and provides ergonomics, allowing large range adjustments (3.8 mm) within 15 minutes by only two iterations. These validation tests have proven the UAP capacity to adjust components of similar size and weight as FRAS components.

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