Cam mover alignment system positioning with wire position sensor feedback for CLIC

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Introduction
Compact Linear Collider (CLIC) imposes stringent pre-alignment requirements [1, pp.602]. They lead to main beam quadrupole (MBQ) positioning requirement of:
- ±1 µm in vertical and transversal in both ends of a single-quadrupole as well as
- 100 µrad in roll

It has been demonstrated that this can be achieved using cam movers and an iterative algorithm [2]. Fig. 1 shows CLIC MBQ and its mechanical stabilization system mounted on cam movers. System characteristics:
- MBQ and stabilisation system dimensions 460 × 510 × 1025 mm(X × Y × Z), weight 570 kg
- cam mover travel ±3 mm, resolution <50 nm

The cam movers were delivered with control electronics which did not allow trajectory manipulation during motion. Therefore, new control system was developed.

Tests
The four positioning algorithms were tested and compared. It was noticed in previous study that positioning deviations caused by uncertainties in the 5 DOF cam mover system’s kinematic model grow with distance from reference position. Therefore, the tests concentrated on target positions near the travel extremities.

A test of 136 sequences was repeated using each of the algorithms. The sequences covered different offset combinations as well as roll targets. Each target was considered reached when deviation was below 1 µm in x- and y-offsets at both ends of the girder and roll deviation was below 5 µrad.

The new control system allows real-time alignment sensor feedback and trajectory modification during motion. The goal was to reach target in one movement. The control system also has three iterative motion control algorithms for the case where fast alignment sensor acquisition is not available.

Test setup
A girder simulating a CLIC MBQ was mounted on five cam movers, as shown in Fig. 2. The cam movers control five DOF (all but along the beam). Two stretched wires are installed on the mock-up and four WPS sensors measure transversal and vertical offsets. The setup is shown in Fig. 3. The five DOF position of the girder is calculated from the redundant WPS data through a least squares algorithm. The measurement system is out of scope but the uncertainty is approximately 1 µm in relative and 5 µm in absolute.

Positioning algorithms
Iterative algorithms
Iterative means that the target position is calculated through a kinematic model and the cam movers are driven to the target. The positioner is then measured and the positioning error is corrected in another movement. This is repeated until the target is reached within specifications.

Synchronous PTP
- Kinematic model gives cam target angles but no trajectory
- NI SoftMotion synchronises cams

Straight-line movement
- Trajectory is calculated completely before a movement
- No monitoring during motion

Complex movement
- The first iteration is executed as in Straight-line movement
- The next ones as in Synchronous PTP

Predictive movement
- The fourth algorithm uses alignment sensor feedback during motion. This means that target position can be reached in one movement even with non-perfect kinematic model.
- Part of trajectory is calculated before movement.
- During motion, trajectory is updated every 1 s.

Predictive movement was then tested with three stop condition parameter sets and reduced amount of sequences. The parameter sets were the original (Set 1), the tightest possible so that all targets were reached (Set 2) and a compromise set between the two others (Set 3).

Conclusions
It was demonstrated that the CLIC positioning requirements for MBQ alignment stage can be met in one movement by using feedback directly from alignment sensors. This predictive movement was compared to iterative algorithms and it performed well both in level of deviation and in positioning time. A trade-off between positioning accuracy with regards to feedback and positioning time can be made depending on requirements.

When applied to a specific system, the predictive movement algorithm can be made faster, especially if there is very little play in the cam movers. Then overshoot is allowed and more aggressive trajectory can be applied.

Literature cited