A MICRO-MOVEMENT TEST FACILITY FOR CERN LINEAR COLLIDER STUDIES

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Abstract

A micro-movement test bench has been constructed to study the problems associated with the support and precise positioning in space of the accelerating structure for the CERN Linear Collider (CLIC). Commercially available micro-movers located at the ends of two interconnected silicium carbide support girders enable several dummy accelerating sections to be displaced with a precision of a few microns over a range of ± 4 μm. In a later stage the movers will be incorporated in an active feedback loop to maintain the position of the sections in space when subject to external disturbances.

Introduction

Over the last few years, a small group of people at CERN has been studying the feasibility of building a 1 TeV on 1 TeV e^+e^- linear collider to satisfy the long-term requirement for a new high-energy accelerator facility [1]. Basic parameters for such a machine have now been established but assume levels of performance or achievement in many areas that are at the very limit of what is currently considered to be feasible. This is certainly the case for the transverse alignment tolerance of the accelerating sections which have been calculated to be ≈ 10 μm (rms) over the total length of one linac (≈ 15 km).

Since normal ground motion excludes a stable static alignment to this precision, a dynamic alignment system is foreseen using a beam-derived signal from beam position monitors incorporated into the main linac accelerating structure to drive precision micro-movers under closed-loop control. This of course assumes that the machine can be pre-aligned with respect to some given reference line in space with sufficient accuracy that the beam stays within the available aperture. It is not known yet:

(i) what this reference line should be (straight or β function dependent) or even how to create it,
(ii) if beam position monitors of sufficient accuracy can be built (1 μm resolution) and
(iii) if a suitable algorithm can be found to treat these signals in a meaningful way.

This general problem of alignment is discussed elsewhere [2].

This paper describes work that is under way to study one aspect of this overall problem - the micro-movement active feedback system.

General philosophy

Each of the two linacs is composed of 50'000 high precision accelerating sections. These copper sections are approximately 25 cm long with an external diameter of 35 mm (± 2 μm) and an approximate weight of 4 kg. To simplify assembly and reduce costs, it is envisaged that several of these sections would be mounted and pre-aligned on a support girder as shown in Fig. 1 before installation in the CLIC underground tunnel. The ends of two adjacent girders would be fixed to a common platform which would itself be activated by high precision movers. The platforms assure continuity of position between units but require care in the design of the attachment from girder to platform to maintain independence of rotational movements.

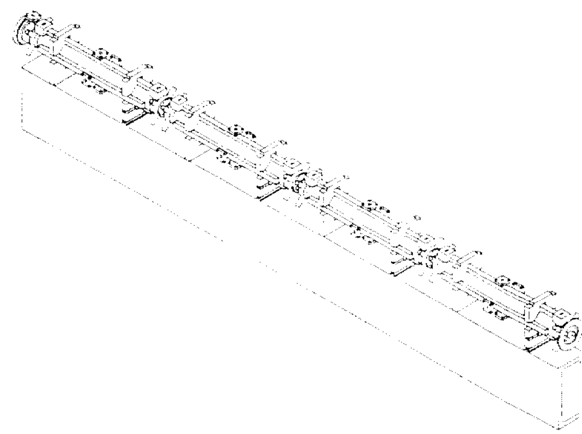

Fig. 1 Conceptual design of the CLIC accelerating structure

Micro-movement test bench

In order to obtain experience in the micron world, a remote computer-controlled micro-movement test bench has been constructed to study the problems associated with the support and precise positioning in space of the CLIC accelerating sections. The test bench is shown in Fig. 2.

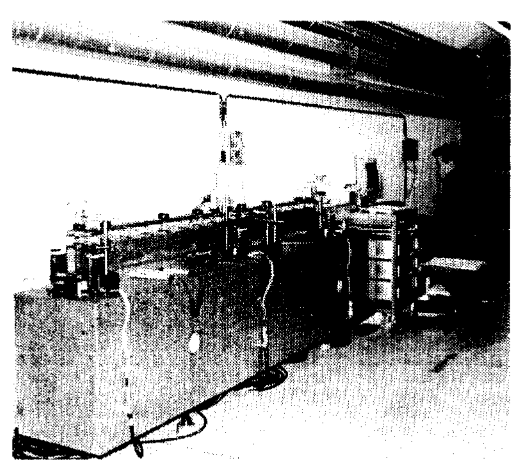

Fig. 2 CLIC micro-movement test bench

The full-size model has been installed on a granite block which serves as a stable outside reference for all measurements. The model consists of two girders supported by three platforms which are each activated by three precision jacks (see Fig. 3).

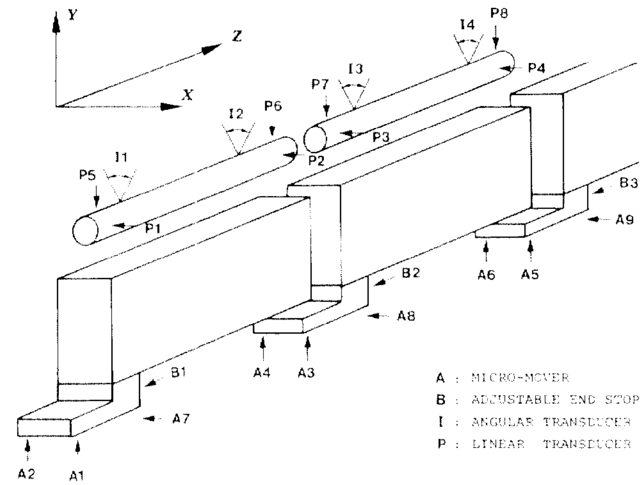

Fig. 3 Support, movement and measurement system

Two jacks in the vertical plane produce vertical displacements and transverse rotations; the third jack is situated, and acts, in the horizontal plane. The box-section girders are made from silicium carbide and for space reasons for this test are 1 m long; CLIC machine girders will almost certainly be longer but the general principle remains unchanged. Four dummy accelerating sections are clamped to each girder via INVAR V-block supports which have been aligned and fixed with a precision of 3 μm in the transverse plane over the 1 m length.

The relative movements of the sections with respect to the reference block are measured with linear and angular displacement transducers in or close to the mid-plane of the interconnecting platforms (see Fig. 3).

The test bench is installed in an unused underground section of accelerator tunnel where the temperature is stable at 16^{o}C with variations over 24 hrs of less than 0.3^{o}C.

Support and displacement system

The three micro-movers and a manually adjustable axial end slop are fixed rigidly to the reference surface of the granite block and are connected to the support platforms via swivel-joint link rods. The adjustable end stop allows precise displacements in the Z direction to be made during the initial alignment.

Each platform supports the ends of two adjacent girders. One of the ends is fixed rigidly to the platform (see Fig. 4); the other is connected to it via two more swivel-joint link rods (see Fig. 5) which allow four degrees of motion (rotation in the XY, XZ, YZ planes and Z displacements). The length of these two link rods is adjustable via micrometric screws so that the axis of the sections on one girder can be aligned in X and Y with the corresponding axis of the adjacent girder.

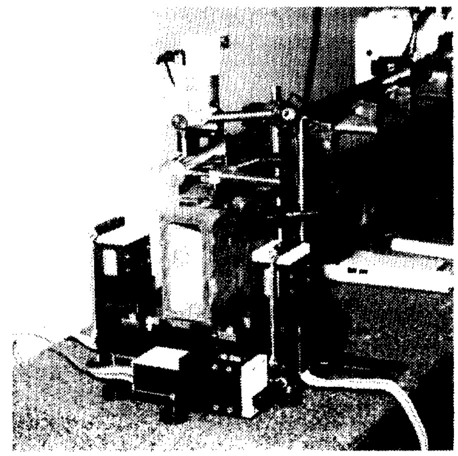

Fig. 4 Fixed end support

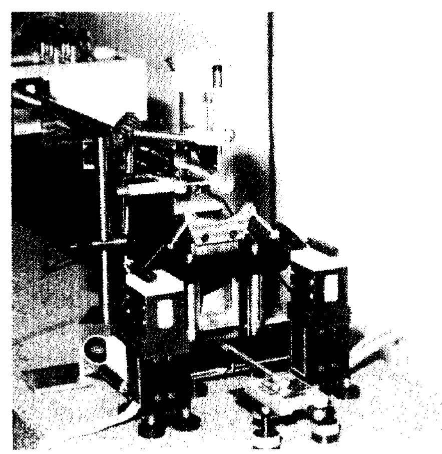

Fig. 5 Moveable end support

Due to the very small diameter of the swivel-joints in the link rods, displacements are obtained almost without friction by rotations around a point without creating stresses in any of the components. This is also the case for movements provoked by thermal expansion of these same components. The disadvantage of such a system is that any movement in one axis produces a small component in the others. This coupling can be minimized by a judicial choice of both the connection points and the lengths of the link rods but is in any case known and can be corrected automatically for each displacement.

Remote control and computer system

The drive and control boxes for the micro-movers and the displacement transducers are connected at the test bench facility to an Olivetti PC 80386 which is linked to the Ethernet network and therefore allows remote operation from any terminal connected to the same network. The Olivetti has been programmed in C under the XENIX operating system.

Two computer test programs are being developed (CINEMA and OPERA). CINEMA monitors the behaviour of the system during displacements. For one or more micromovers and given displacements, the program calculates the theoretical displacements that should occur at the various transducers and compares them with the values obtained. This program is operational and preliminary results are given below.

OPERA on the other hand drives the micromovers so as to obtain and maintain a specified set of transducer readings. It is the first step towards an active closed-loop alignment system. This program is not yet operational.

Micro-movers

One of the aims of this test bench experiment was to see what precision and frequency response could be obtained from commercially available micro-movers so that areas where improvements were necessary could be identified. MF 08 PP movers made by the firm Micro-control for the micro-positioning of optical fibres have been used. The stepping motor drive has a resolution of 0.1 µm and an absolute precision of 1 µm over ± 4 mm

Transducers

Linear displacements of the dummy accelerating sections are measured with SYLVAC P10L transducers. This contact probe uses a capacitive vernier measuring system to obtain a resolution of 0.1 µm and an absolute precision of 1 µm over a range of ± 5 mm.

Angular movements are measured by SENSOREX 41300 level gauges which have a resolution of 10 µrad over a range of 50 mrad.

Support girders

Silicium carbide was chosen for the girder material because of its high stiffness to weight ratio (E = 21000 daN/mm^2; ρ = 2.65 g/cm^3), its low thermal expansion ($\alpha = 4.8 \times 10^{-6}$) and its good damping characteristics.

Perturbations

The perturbations come from both natural and man-made phenomena and have widely varying amplitudes and frequencies. The most common natural disturbance for accelerators comes from the slowly varying distortion of underground tunnels which can produce displacements of several millimeters. Man-made perturbations (rotating machinery, transport, vehicles, building sites, etc.) are normally associated with higher frequencies (> 5 Hz) and smaller amplitudes (microns).

The test set-up described in this paper has been designed to permit :

i) relatively large displacements for initial alignment, and,

ii) micro-movements for correction of slowly varying perturbations during CLIC operation.

Correction of disturbances with frequencies > 1 Hz could if necessary be achieved by incorporating piezo-electric movers with a ±10 µm displacement capability in series with the movers that have been used.

Preliminary Results

A limited number of preliminary measurements have been made to evaluate the sensitivity and coupling of this support and movement system. The results are summarised in the following tables and use the notation given in Figure 3.

Sensitivity

P1	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*
8	7	9	8	11	10	10	10

Measured values (in 0.1 µm) on all linear displacement transducers (P1-P8) for a 1 µm movement of all movers (A1-A9).

Radial Coupling

	P1	*P2*	*P3*	*P4*
Measured	+ 9780	+ 181	- 2	- 3
Theoretical	+ 9802	+ 198	0	0

Measured and theoretical values (in 0.1 µm) for a radial movement of 1 mm (10'000 steps) at A7.

Vertical Coupling

	P5	*P6*	*P7*	*P8*
Measured	+ 9794	+ 176	- 2	0
Theoretical	+ 9802	+ 198	0	0

Measured and theoretical values (in 0.1 µm) for a vertical movement of 1 mm (10'000 steps) at A1 and A2.

Tilt Coupling

	I1	*I2*	*I3*	*I4*
Measured	4.529	4.543	0	0.006
Theoretical	4.545	4.545	0	0

Measured and theoretical values (in mrad) for vertical movements of + 0.5 mm (5'000 steps) at A1 and of - 0.5 mm (5'000 steps) at A2.

References

[1] W. Schnell, "The Study of a CERN linear collider CLIC", CERN/LEP-RF/88-48 and CLIC Note 77.

[2] G. Fischer, M. Mayoud, "Some thoughts on linear collider alignment and mechanical stability", CLIC Note 61, 1988.

Acknowledgements

The design, fabrication and assembly of the micro-movement test bench has resulted from a close collaboration between CERN and the French firm Micro-control. The authors would like to acknowledge in particular the contributions of Messieurs Gaillard and Désailly of Micro-Control, Messieurs Gave and Chavanel from CERN and Dr G. Fischer of SLAC who, as a CERN visitor, helped to initiate this programme of work.