PRE-ALIGNMENT OF CLIC USING THE DOUBLE-WIRE METHOD

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Abstract

The pre-alignment and active control method for the Compact Linear Collider (CLIC) is described. Two new types of instruments are used in this system - a biaxial Wire Positioning System (WPS) which uses a stretched wire as the spatial reference, and a capacitive three axes Tilt Meter System (TMS). The instruments, and the way they are used with the well-known Hydrostatic Levelling System (HLS) are described.

1 INTRODUCTION

Transverse alignment tolerances of about 10μ (rms) are required for the Compact LInear Collider (CLIC) [1] in order to limit the emittance blow-up due to transversely deflecting wakefields to reasonable values. An active alignment system using precision micromovers is proposed to achieve these tight tolerances. The length of each CLIC linac for the 500 GeV centre-of-mass machine is about 4 km. Since the CLIC scheme is a two-beam scheme, each linac in fact comprises two parallel linear accelerators about 550 mm apart. The accelerating structures and beam position monitors of each linac are supported by precisely pre-aligned V-blocks sitting on SiC girders. The ends of two adjacent girders are connected by swivel-joint link rods to a common platform which is driven by three remote-controlled 0.1 μm resolution stepping motors (Fig.1). The inter-girder articulation points are 1.41 m apart. The quadrupole supports are independent of the girder supports and are driven by five identical stepping motors. The quadrupole support platforms are located above the girders.

2 GENERAL DETAILS OF THE METHOD

Aligning the linac in this case means aligning the articulation points of the girders, and the magnetic components. One linac has about 2780 girders and 400 magnetic components.

The standard deviation on the relative position of three consecutive intersection points or three consecutive magnetic components must be less than 5 μm. To obtain this result and to monitor continuously the geometry of the linacs, it is planned to use a technique known as the "double-wire method".

This involves stretching parallel rows of wires parallel to the axis of the linacs. The wires overlap half way along their own length and form a geometric reference network for the alignment and monitoring operations. The articulation points of the girders and the magnetic components are fitted with sensors which use the wires as their reference.

Three types of measuring instrument are foreseen:

a) the hydrostatic levelling system (HLS), which has already been fully described and widely used;
b) the tilt measuring system (TMS), a new instrument currently under development which measures, to a precision of the order of 0.1μrad, angles and accelerations along two horizontal axes, and accelerations along the vertical axis;
c) the two-axis wire positioning system (WPS).

3 WIRE POSITIONING SYSTEM (WPS)

The WPS is an instrument that measures, along two axes and to a precision of the order of one micron, the distance between its mechanical axis and a stretched wire (Fig.2).

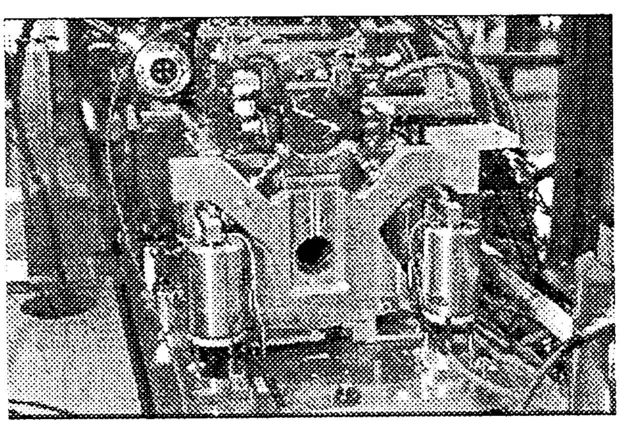


Figure 1: Inter-girder connection

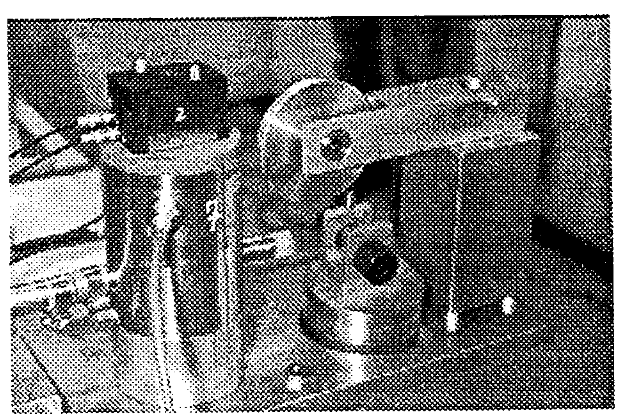
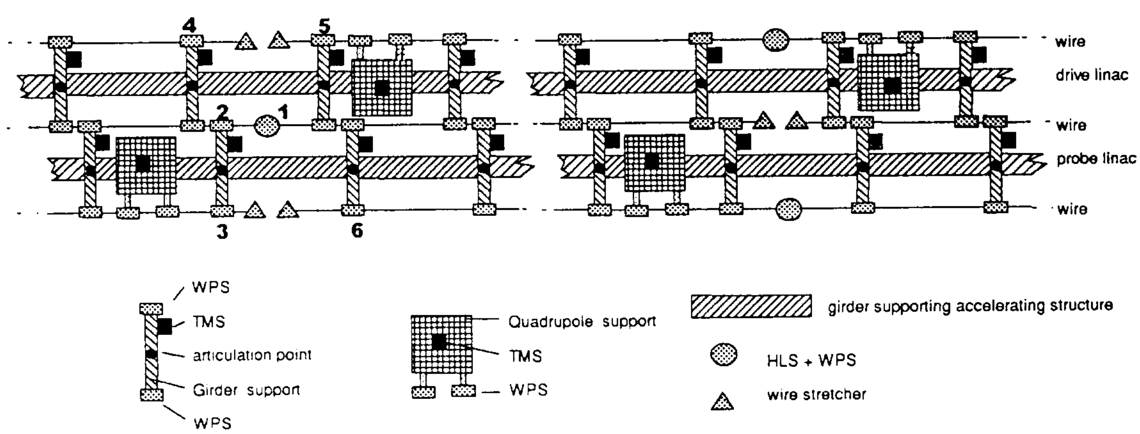


Figure 2: WPS + HLS + Tensioner

The technique used is capacitive measurement. The sensor and its target, the wire, form a variable capacitor. The measurement range along the two axes is ± 5 mm. For this range, the instrument delivers a voltage of 0 to 10 V per axis. The WPS has the form of a rectangular parallelepiped (46x46x70 mm), it has two opposite electrodes per axis this gives a good signal linearity (the most linear zone is around the mechanical centre of the sensor) and also eliminates any symmetrical cross-sectional variations of the reference wire. To install the wire, the instrument opens diagonally with a horizontal sensor and a vertical sensor in each half. Two pins are provided for the precise re-assembly of the two parts. The maximum error after this operation is 2 μm. The sensor consists of passive metal and ceramic components. If necessary the electronics can be located some tens of metres away for protection against radiation and the effects of magnetic fields. The electronic sensor assembly is very stable. Measurements taken over several days under laboratory conditions have shown variations of only 3 μm. Although the inherent capacitance of the cable connecting the sensor to the electronics is several orders of magnitude greater than the capacitance of the sensor this is not in this case detrimental due to the use of the special total shielding technique. The only constraint is that the electronics are adjusted for a given cable length.

Since the instrument is both stable and reproducibile it can be reliably calibrated. It was found that all the instruments have a nearly identical calibration curve, this is a direct result of the manufacturing precision. The calibration curves have a highly linear central zone (± 1 mm) and an outer zone of reduced linearity. The prototype sensors do have a defect, however, namely that the electrical zero does not correspond to the mechanical zero and varies for each sensor. Deviations of up to 50 μm have been observed. This defect will be corrected in the next batch of sensors. Once that has been done, it will be possible to use all the sensors with the same calibration curve; the maximum precision of ± 1 μm will naturally only be obtained in the highly linear zone. Outside this zone the deviations may be as much as 50 μm.

Figure 3 : Clic alignment : schematic plan view



3 THE WIRE

The wire used is actually a twisted wire made out of very strong low density carbon-fibres to minimise deflections. It conducts electricity sufficiently well to allow capacitive measurements.

The characteristics of the wire are as follows:

- apparent average diameter: 0.32 mm
- weight of 100 m of wire: 8.522 g
- deduced density: 1.06 kg/dm^3
- elastic limit: approximately 9 kg
- mass of counterweight used: approximately 6 kg.

The drawback of this wire is that in the long term some fibres eventually break and cause non-symmetric cross-sectional differences which distort the measurement. To eliminate this drawback, a method of impregnating the wire that will only cause a slight variation in the linear weight is being developed.

To be able to consider the wire as a reference it is vital to have a precise model of the stretched wire in the vertical plane under a given load. For a 60 m carbon fibre wire tensioned with 6 kg, a change in deflection of 1 μm may be obtained by modifying (i) the counterweight by 1 g (ii) the wire length by 3 mm (iii) the position of the WPS by 2 mm in the zone where the wire has its maximum slope, or by 27 cm in the horizontal part (iv) the linear weight by less than 0.01 g.

It is actually the linear weight which, with a very slight variation, has the greatest impact. As it is impossible to know this value precisely, it will be necessary during the calculations to consider the linear weight as an unknown and to introduce other parameters, namely the heights of the ends and the mid-point of the wire.

A series of experiments has been conducted to determine the catenary of the wire with great accuracy. These measurements were carried out using a system that combined the HLS and WPS (as shown in figure 2). Once the catenary of the wire had been determined, the theoretical shape was calculated using the known parameters: length of the wire, dead weight, an estimated value of the linear weight of the wire and the heights of the ends and the mid-point of the wire. Comparison of measured and calculated values resulted in a standard deviation of less than 5 μm.

5 DOUBLE WIRE METHOD APPLIED TO CLIC

For the reference metrology of CLIC, the technique involves stretching wires approximately 60 m long from end to end on either side of the linacs. There are three rows of wires, of which one is common to both linacs. The wires in each row overlap. The wire attachments of one row are located at the mid-point of the wires in the opposite row. The ends of the girders are fitted with two wire positioning systems precisely located with respect to the articulation point. These instruments determine the position of the articulation point with respect to the wires and define the distance between two wires. The quadrupoles have two sensors which are on the same wire (see figure 4).

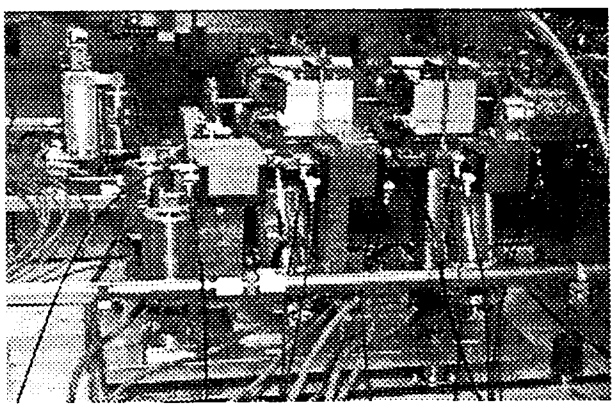


Figure 4: Quadrupole support

The points where the wires are fixed are deliberately chosen not to be the points that have to be aligned. The wire is fixed at one end and has a counterweight attached to the other. It passes over a knife-edged pulley which keeps it tensioned to a precision of 10^5 N. The model assumes that the ends of the wires are at the longitudinal mid-point of the sensors fitted to the end of the girder closest to where the wires are really fixed. To model the wire in the vertical plane, the heights of the ends and the mid-point of the wire have to be determined. The mid-point height (point 1 in figure 3) is simply measured using the combined HLS-WPS system shown in figure 2. Measurement of the ends could be done in the same way but is in fact done in the following more complicated way to minimise the number of HLS-WPS systems used. Since the WPS unit (point 2 in figure 3) is 100 cm at most from the next nearest HLS the height of point 2 can be calculated from point 1without significant error using the theoretical model. The height of point 3 is then determined from point 2 using the tiltmeter reading. A similar strategy is adopted to determine the heights of points 4,5 and 6 from the height of point 1.

6 ALIGNMENT OF CLIC TEST FACILITY (CTF)

It is planned to install the instruments and support systems described in this paper in CTF2 in June 1997. A pre-assembly of two of the 30 GHz modules is shown in figure 5. This will be a unique occasion to test this system in a working accelerator environment and should produce valuable information for further developments.

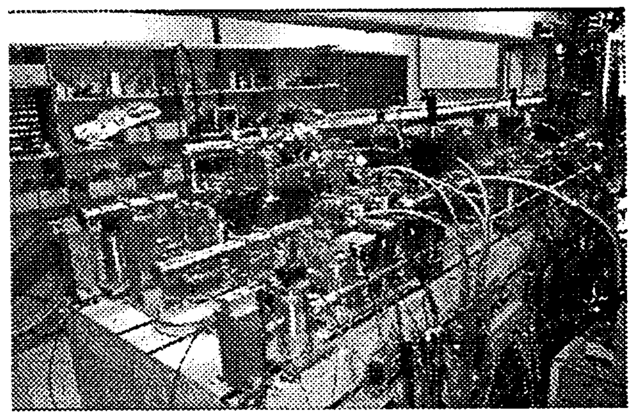


Figure 5: Pre-assembly of CTF2 30 GHz modules

7 CONCLUSIONS

The WPS has been shown to be a very good metrology instrument, and a stretched wire can be used as a two axis spatial reference. As for the double-wire method, some simulation work has been done. Preliminary results have reinforced our belief that the method is valid for the alignment of CLIC, but a great deal of work remains to be done before our study is complete.

REFERENCES

[1] H.Braun and 10 co-authors: 'CLIC-A Compact and Efficient High Energy Linear Collider', PAC95, Dallas, May 1995.

[2] W. Coosemans, H. Mainaud, "Métrologie linéaire : écartométrie biaxiale et fil tendu", CERN, CLIC Note No 326, Septembre 1996.

[3] The firm Fogale Nanotech, "Sensors and actuators for alignment of large machine components", 190 Parc Georges Besse, 30000 Nimes, France