Bending of End-Cap Electrodes

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Abstract

The copper-polyimide electrodes have to fit into the accordeon shape of the lead-steel absorbers. This note describes the tools and the procedure used to bend the end-cap electrodes.

1 Introduction

The polyimide-copper electrodes have to fit inside the absorbers accordeon shape, and thus, must be bent to the same geometry.

In the end-cap, folds are radial and the folding angle varies along the folds, becoming sharper at large radii, while the curvature radius remains constant [1]. Before bending, electrodes have a fan-like shape, and the folding lines are not parallel (figures 1 and 2), becoming so at the end of the bending operation. Such a geometry makes the end-cap electrodes bending a difficult task.

The main requirement on the folds follows from the 50 μm dispersion tolerated on the gap thickeness, which leads to a ± 150 μm tolerance on the distance between two neighbouring folds [2].

Several solutions have been considered. Two of them are described in section 2, while the choosen one is presented in section 3. The bending of module 0 electrodes in summer 98 and its outcome is shown in section 4.

2 Considered methods

In the beginning, we considered naturally the already used methods to bend the end-cap prototype electrodes (spanish fan), and the end-cap lead abosrbers.

2.1 Prototype method

This method uses an industrial press. The folds are made one by one with a single knife, at a constant angle, which is the smallest angle of the considered fold. The real geometry is then recovered out of the press by using a retractor. The exact position of the folding knife on the electrode surface is determined by a stop-block system.

The use of a retractor gives asymetric folds, and the stop block system is unable to achieve the required accuracy in fold position. This method has been rejected.

2.2 Absorbers method

We considered also a "crocodile" multi-knives automatic press, as for the lead absorbers [3]. Although this solution is the most confortable one, it has been ruled out. The complicated kinematics of the knives, dynamic aspects (rigidity and mass difference between absorbers and electrodes) and necessary new developments to minimize the transverse stresses on electrodes make such a device rather expensive [4].

3 End-cap electrodes bending system (choosen method)

3.1 Method

Our bending system consists of a bending knife, a foam rubber table and two metallic pins (figure 3).

The knife is attached to an industrial press. It has the required curvature radius (3 mm for D type electrodes and 3.25 mm for C electrodes). The variable angle is obtained by tilting the knife. The sharper angle is then obtained on the highest side of the knife.

During the operation, the rubber table pushes the electrode upwards, and the folding is performed without sliding nor tractive force.

After bending, folds open up by about 10°, due to material elasticity [5]. To obtain nominal angles, we over-fold by the same amount.

3.2 Fold position

The electrodes are placed on a foam rubber table. The fold positions are determined by the T-shaped holes drilled on the extensions of the electrodes [6]. These holes house the metallic pins at each end of the fold. The pins are mounted on a spring system that makes them draw back during the knife movement (figure 4).

One of the pins (at large η) can move along the fold direction. The pins have a square shaped surface of 10 mm x 10 mm, while the T-holes have a useful area of 10 mm x 20 mm. They are longer than the pins along the fold direction. This allows a precise centering in the transverse direction, and to make up for an eventual displacement of the hole along the fold direction during the fabrication process.

There are also two additional pins to deal with the special case of the first and last folds of D electrodes. These two folds have no T-shaped holes at their ends (figure 2) due to the limited polyimide usefull width [6]. Therefore, we use their neighbouring holes, centered with two additional pins which are not aligned with the bending axis.

3.3 Folding knives

To be able to make alternately folds on the two sides of a C electrode with one simple electrode rotation, two C-like knives are mounted on the press, each with its own rubber table and pins (figure 5).

Such an apparatus is difficult to achieve with D-like knives, given the limited size of the industrial press and the big length of D electrodes ($\sim$ 1.5 m). Another solution has been worked out. Both sides of a single knife are equipped with machined profile to perform the folds. The angle variation is inverted on the two folding sides (figure 6). This system allows to have the still unfolded side of the electrodes always on the same side of the press, and thus, makes the procedure easier.

3.4 Control devices

At the end of the folding, electrodes are placed between the two jaws of a metallic control template, with edges machined to the exact shape (figure 7), and coated with a thin foam layer in order to protect electrode surface. An electrode is accepeted if it fits (without constraints) inside the template. The extensions for centering holes are then cut away.

All the bending and control tools were manufactured by RIPM company (13760, Saint Cannat, France).

4 Module 0 electrodes bending

During summer 98, 21 D electrodes from Cicorel and 6 C electrodes from MCB were folded at the RIPM shop.

First, we had to tune the knives tilt, and to find the most convenient foam hardness. We noticed that D electrodes require harder foam than the C's.

4.1 C electrodes bending

C electrodes didn't show any problem. They were handled manually (with gloves), and their folding went fast. Their control template was used, while the D template was not ready at that time.

4.2 D electrodes bending

The consecutive steps for the bending of D electrodes were:

- Mounting of the foam table and the bending knife (with the appropriate tilt) on the press.
- Mounting of special pins for first and last folds.
- Perform the first and last fold.
- Dismount the special pins and mount the ordinary ones.
- Perform the other folds. After each fold, the bending side of the knife is changed by rotating the knife, and the electrode is rotated by 180° around the horizontal axis parallel to its small dimension. This enable us to perform the next fold.

D electrodes were handled between two rectangular plates of expanded foam. The plates were moved back gradually before performing each fold. We were able to fold one D electrode in 40 minutes.

4.3 Outcome

The D electrodes were folded in three batches. Except for the first and last folds (see below), the folding of the first batch went well, and the result was very satisfactory. The two last batches showed an enlargement in folding angles of about 10°, even after pushing the knife to its maximum distance. They were clearly out of specifications, but we managed to mount them in module 0. This is not yet understood (ageing of foam ? room temperature difference ?...).

We were not able to perform the first and last folds of D electrodes. The lack of copper in the flat extensions makes the electrode very elastic in these regions. The folds were slightly marked on the curved region but the angles opened up as soon as the knife was removed. The addition of copper on the flat extensions (used for read-out strips, HV routing and ground contacts), would improve the quality of these folds.

We also noticed that the value of some silk-screened resistors between sampling 1 and 2 on the convex side of the fold have increased after the folding (figure 8). It seems that the minimal distance between the edge of the curvature and the edge of the resistor, which is 3.5 *mm* should be increased.

5 Future improvements

For the future, we forsee to improve the handling tools, to use a dedicated press, a harder foam, and to work in a clean area. Changes to the D electrodes design (more copper on the flat extensions, increased distance between resistors and folds) are being discussed.

Acknowledgments

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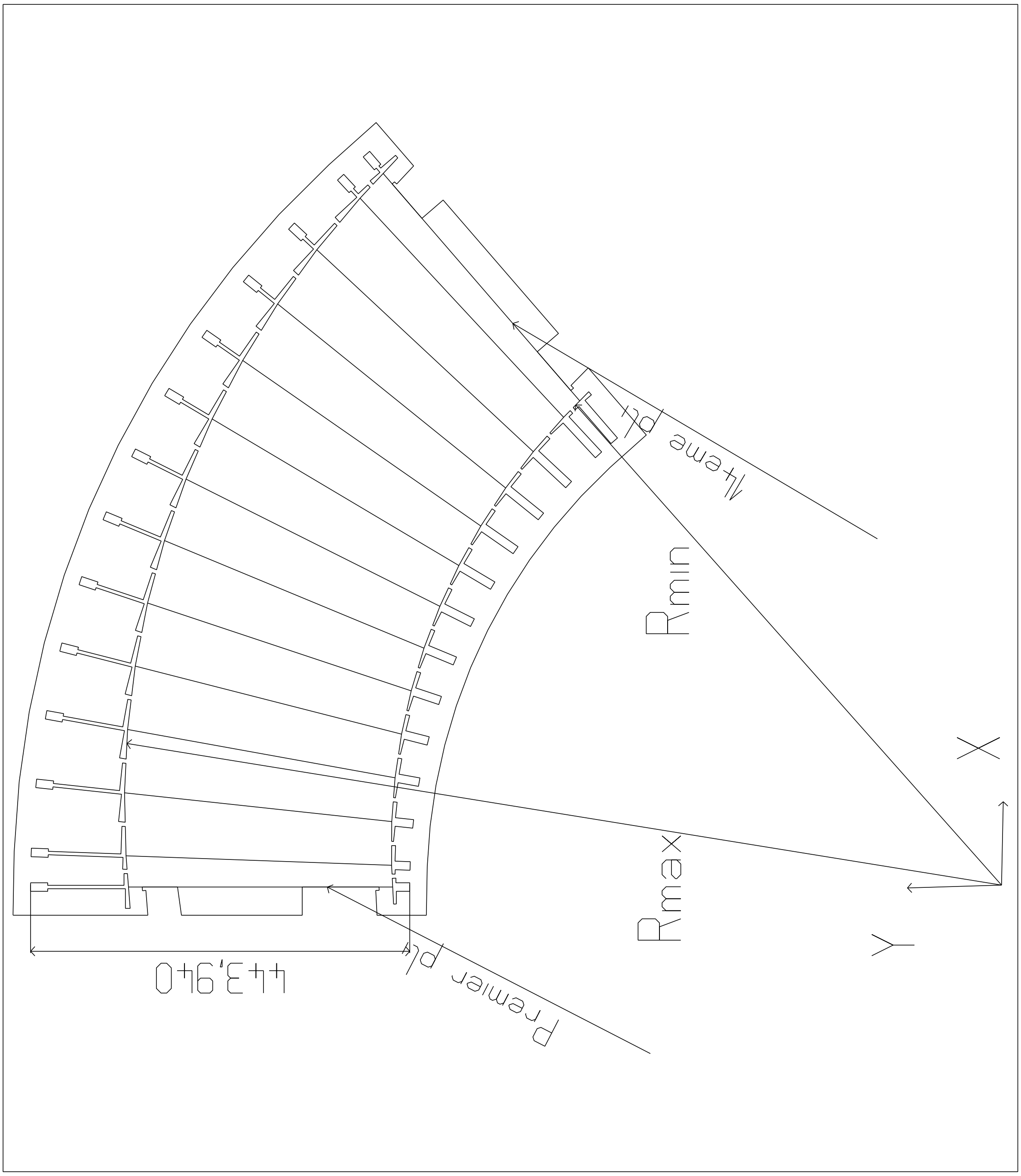

Figure 1: Schematic view of a flat C electrode with the folds axis.

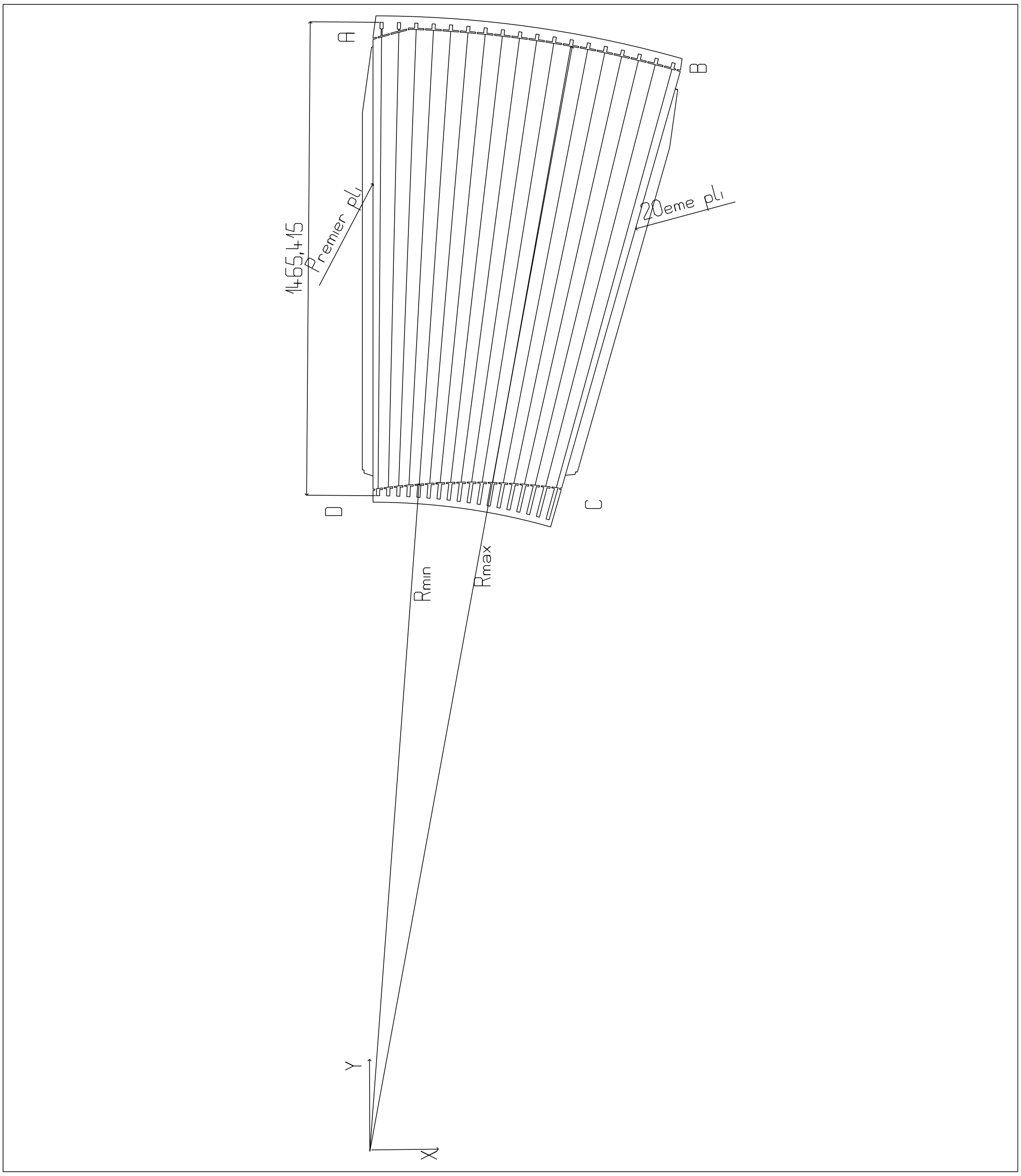

Figure 2: Schematic view of a flat D electrode with the folds axis.

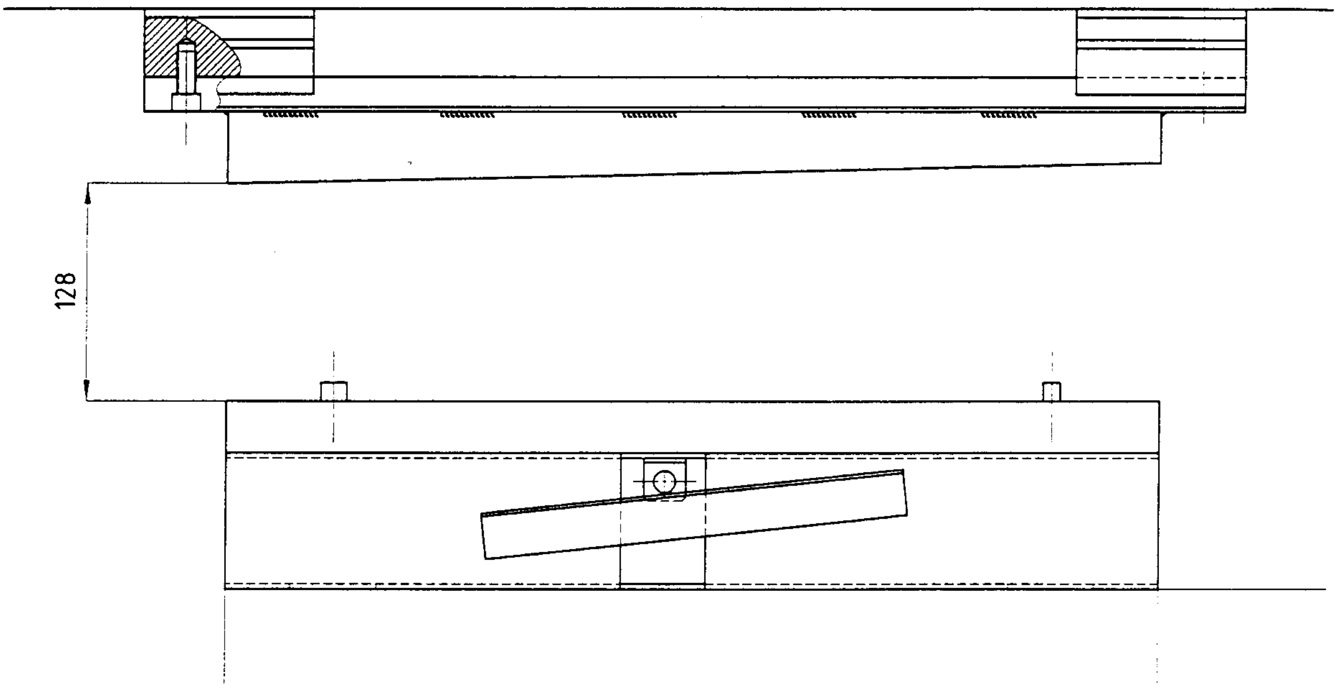

Figure 3: Overall view of a bending device: the tilted knife, and the foam table with its two pins.

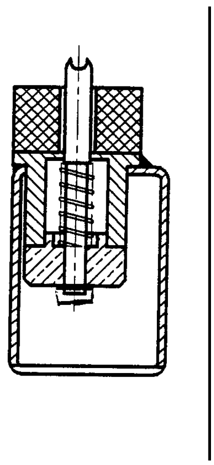

Figure 4: Centering pin mounted on its spring.

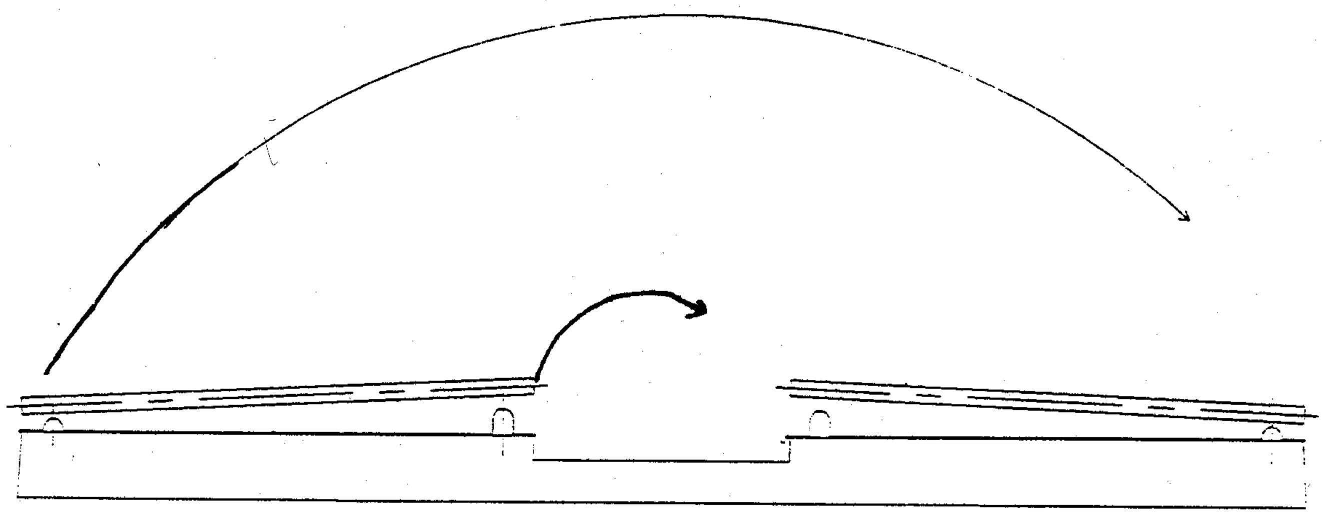

Figure 5: Folding procedure for two consecutive folds of C electrodes.

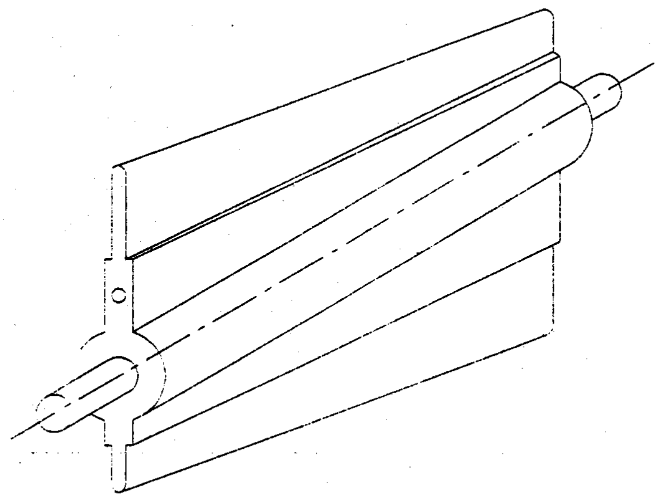

Figure 6: Folding knife for D electrodes.

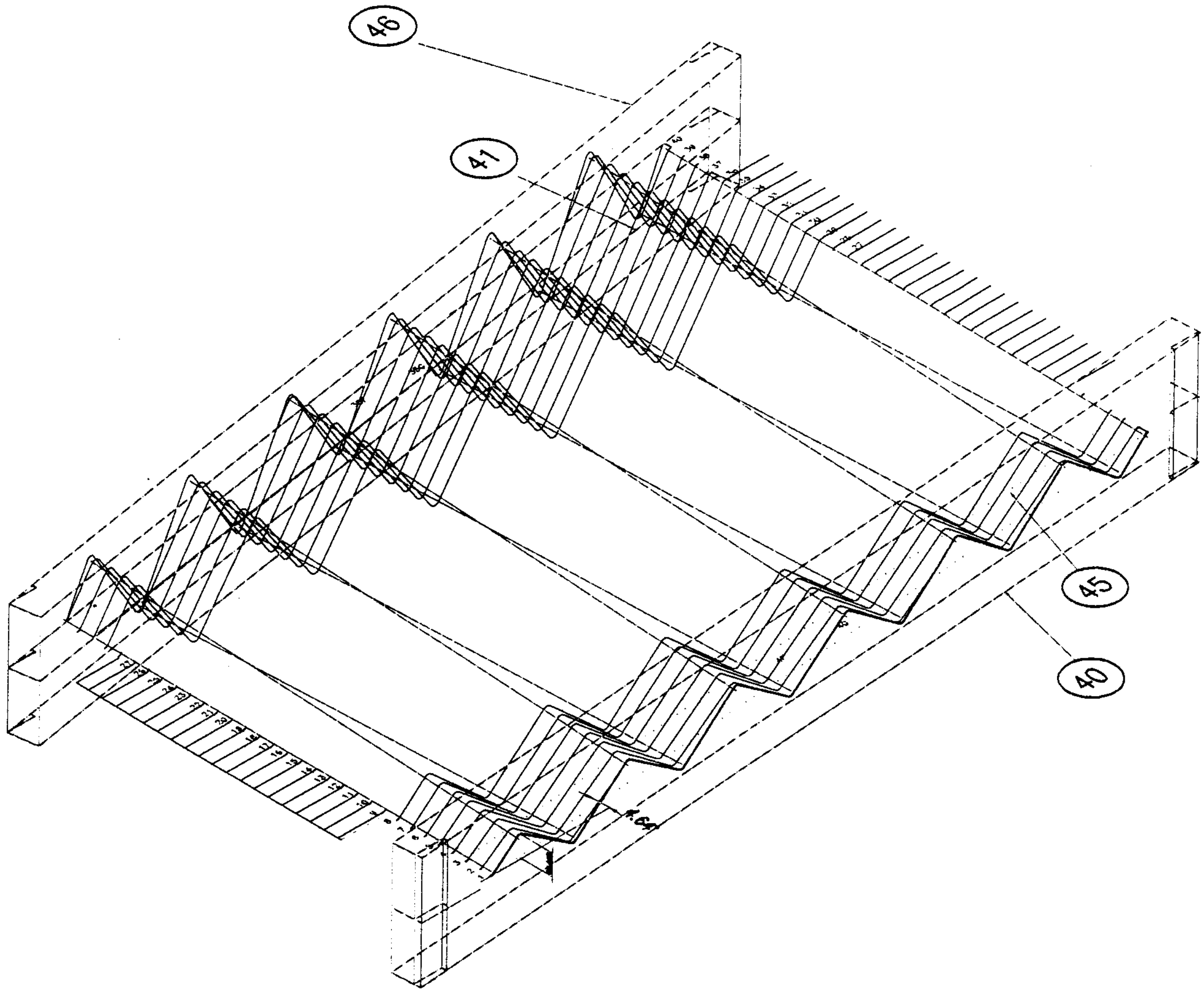

Figure 7: Schematic view of the lower jaw contours of the control template for C electrodes.

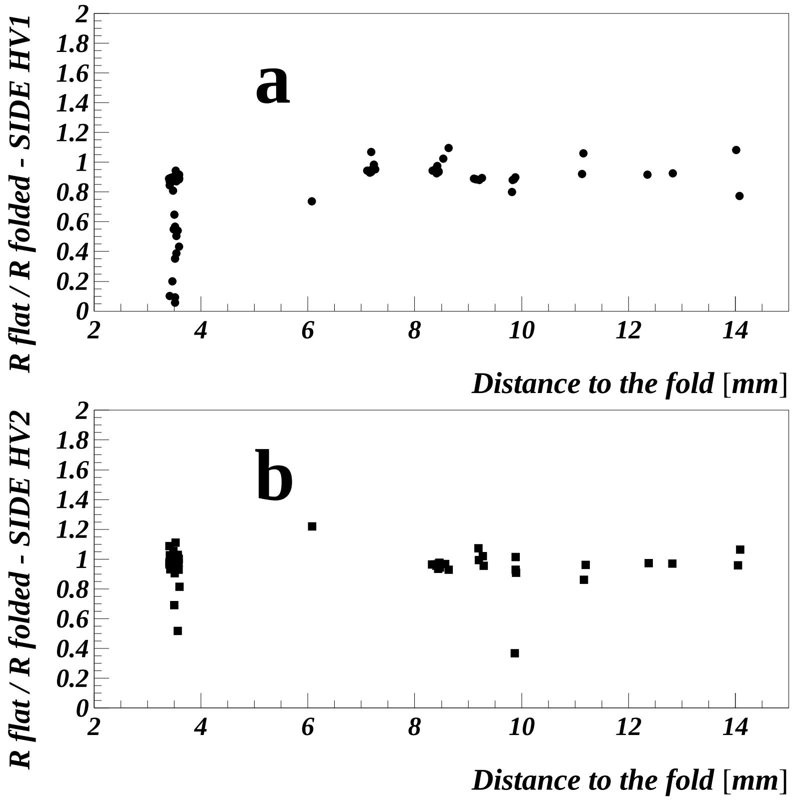

Figure 8: R_{flat}/R_{bent} ratio versus the distance to the fold for S1/S2 separation resistors for convex side (a) and concave one (b).