Fermilab

TS-SSC-92-023 *
February 22,1992
Masayoshi Wake

DCA313-316 Axial Strain Change

Axial strain of the long 50 mm magnets has been showing same sort of behavior of 40 mm magnets. Typically, tension produced by the electro magnetic force at the end part of the coil is transferred to the skin shell of the magnet over a distance of about 2 meters. The stress change in DCA311 and 312 has been already reported[1]. This note displays some more variety in the axial strain distribution.

Calcualtion with Spring Model

Since, no hysteresis has been observed in the strain-current plot[1], the mechanism of axial interactive force is not limited by the friction between collar and yoke. The axial force, $f(x)$, between the shell and the coil is produced by the sheer stress in the boundary or more likely produced by the tilting of the collar. If the displacement of the coil at the position x is $d(x)$ and that of the skin is $D(x)$,

$$f(x) = k(d(x) - D(x)) \tag{1}$$

where, k is the sheer spring constant. This force is balanced in both side by the stress distribution. Therefore,

$$-f(x) = E\frac{\partial^2 D(x)}{\partial x^2} \tag{2}$$

$$f(x) = e\frac{\partial^2 d(x)}{\partial x^2} \tag{3}$$

where, E and e are the elastic constants. Substituting (2) and (3) into (1),

$$\frac{\partial^2 f(x)}{\partial x^2} = -k(\frac{1}{E} + \frac{1}{e})f(x) \tag{4}$$

The length of the magnet is long enough to use the solution under the boundary condition $f(\infty) = 0$. The solution is:

*Distribution: R.Bossert, J.Carson, S.Delchamps, W.Koska, M.Kuchnir, M.Lamm, G.Pewitt, J.Strait

[1]J.Strait, TS-SSC 91-240

$$f(x) = Aexp(-\sqrt{k(\frac{1}{E} + \frac{1}{e})}x). \tag{5}$$

Therefore, the strain $S(x)$ has the form of:

$$S(x) = \frac{\partial D(x)}{\partial x} = \frac{1}{E}\int f(x) + const \tag{6}$$

If the total electromagnetic force is F,

$$F = es(\infty) + ES(\infty) \tag{7}$$

and

$$s(\infty) = S(\infty) \tag{8}$$

another boundary condition at the end of the magnet is:

$$S(0) = 0 \tag{9}$$

Then the strain and force are given by:

$$S(x) = \frac{F}{e+E}(1 - exp(-x\sqrt{k(\frac{1}{E} + \frac{1}{e})}) \tag{10}$$

and

$$f(x) = F\sqrt{\frac{Ek}{e(E+e}}exp(-x\sqrt{k(\frac{1}{E} + \frac{1}{e})} \tag{11}$$

The strain is zero at the very end and exponentially increases toward a certain value to the center. Depending on the sheer spring constant, the range of change at the end is determined. This formula roughly explains the measured data.

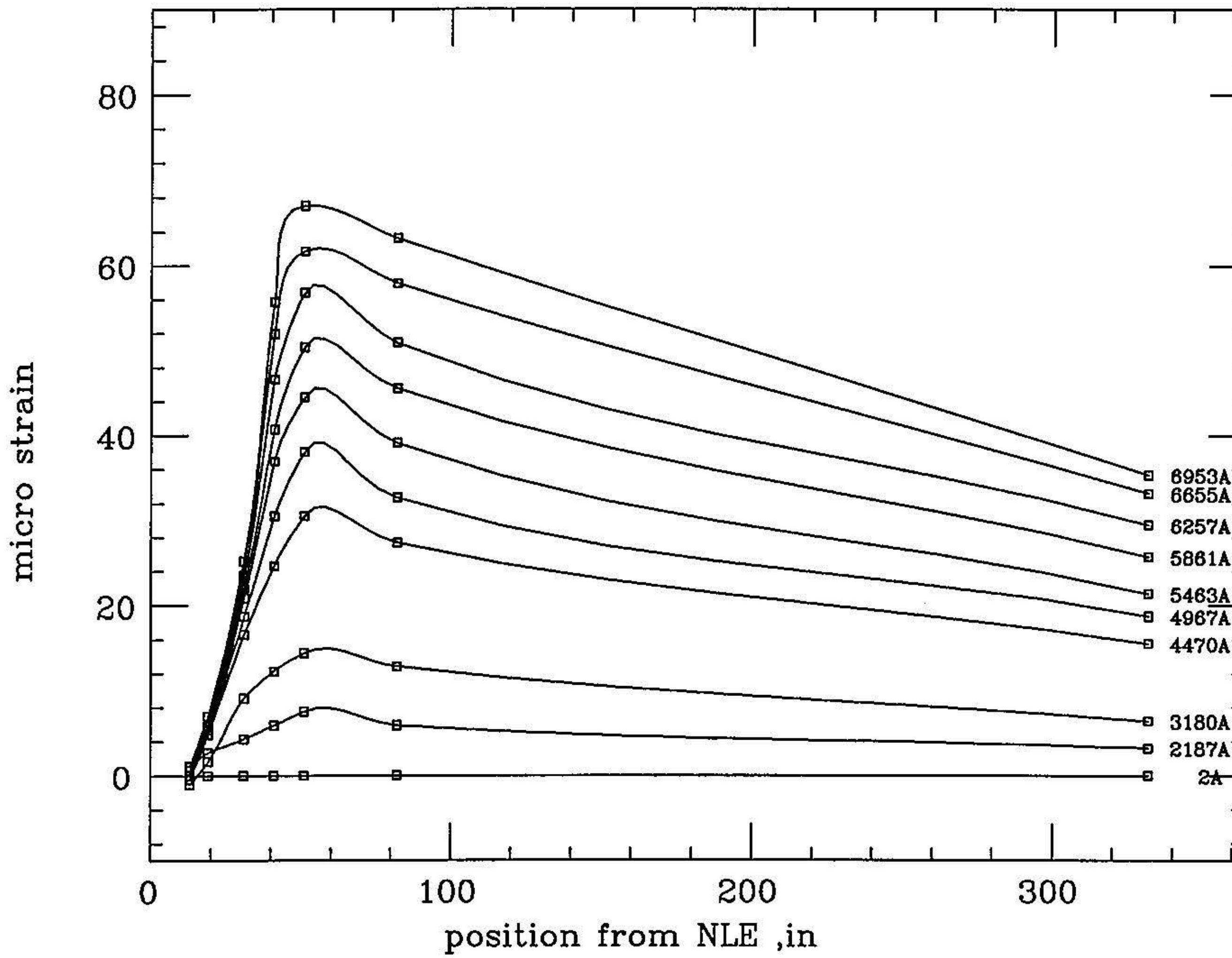
Measured Data

The strain data were extracted from "CA-files" and subtracted by the strain at 0 or very small current to have the electro-magnetic part of the strain. These strain gauges are uncalibrated one but the subtraction of zero current value automatically compensate the "R_0" of the strain gauge. DCA314 had bad gauge in 89 inch and 295 inch position from the non lead end. DCA313 looks as if it had a very large strain until the magnet was trained. This is due to the reference error in the database. However DCA313 changed the axial strain more than other magnets as a result of the excitation cycle. This might be related with the unusual low current quench in the initial excitation.

The large decrease of strain[1] in the center of the magnet observed in DCA311 was not typical in these new magnets. DCA315 even showed the increase of the strain at the center of the magnet. If we interpret this as the effect of the support posts of the cryostat, we have to say there is so much difference in the assembly of the support post for every magnet. More pronounced structure of the strain was observed at the end part. Since this structure is common for all the magnet except DCA311 and DCA312, there must be some systematic reason for it. 10.3 inches from the end are the end filler. Next 10 inches are monolithic yoke. The post is located at 47" position. The relationship withe these geometry is no yet clear.

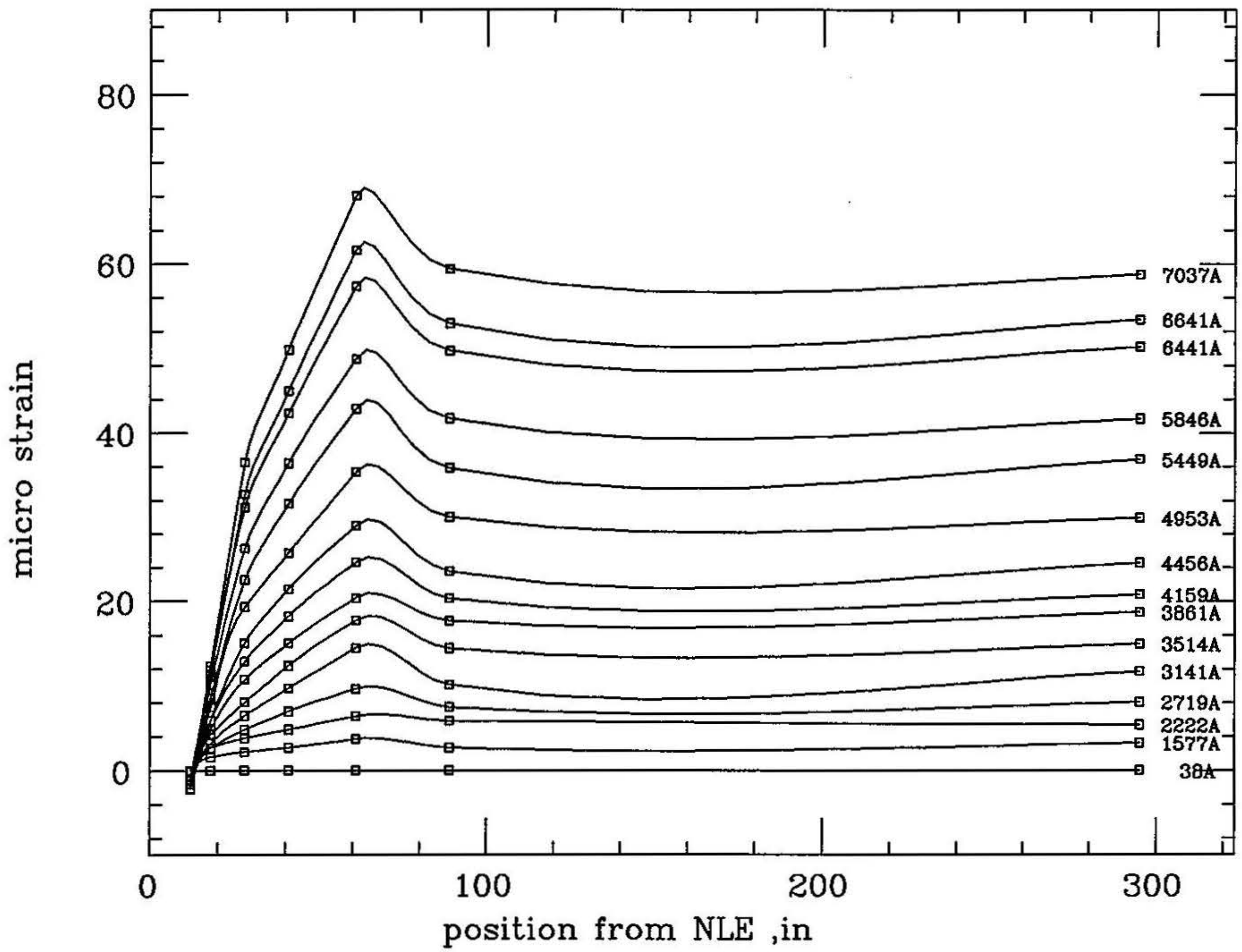
CAφφ6

DCA311 E-M axial strain



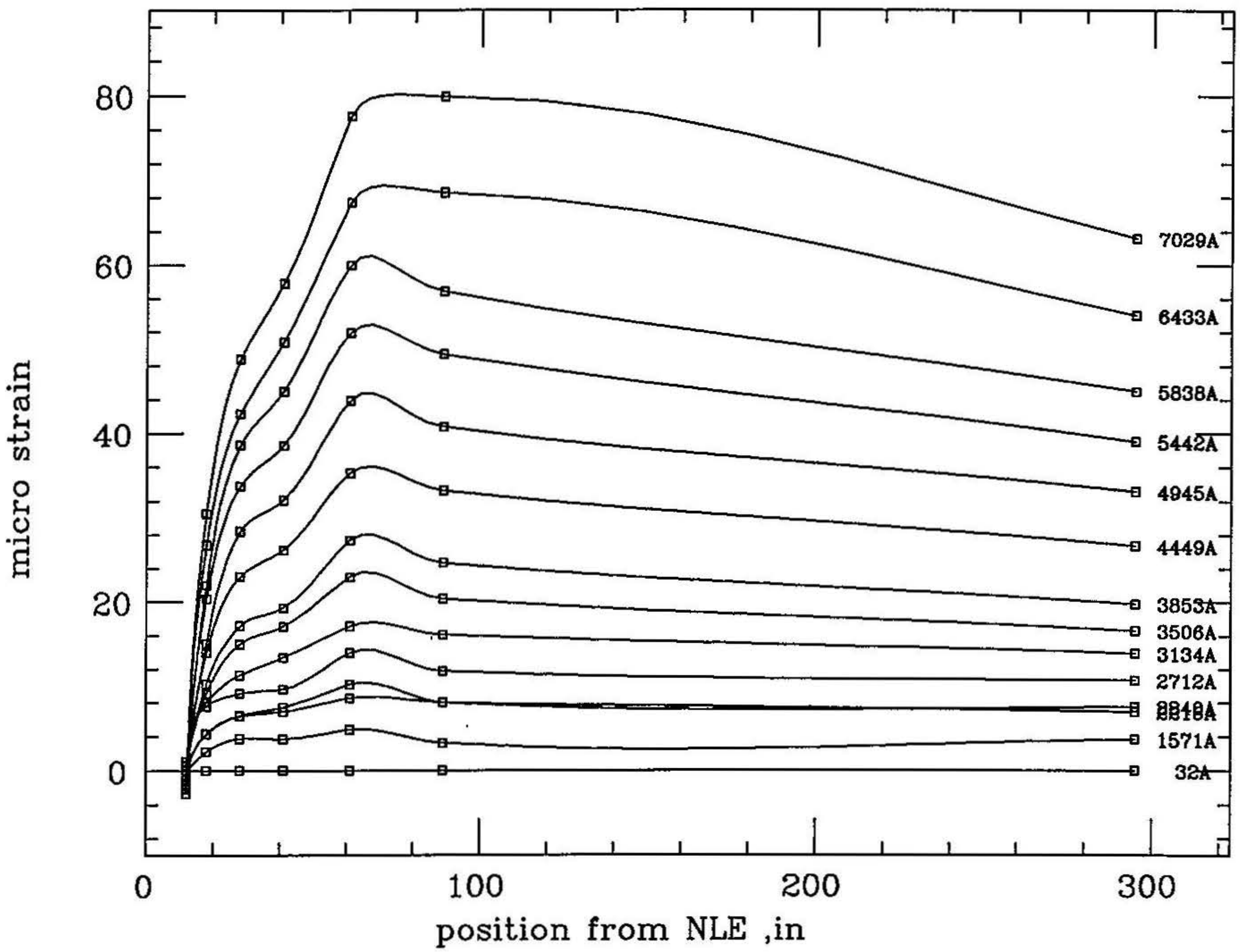
CA005

DCA312 E-M axial strain



CA ØØ5

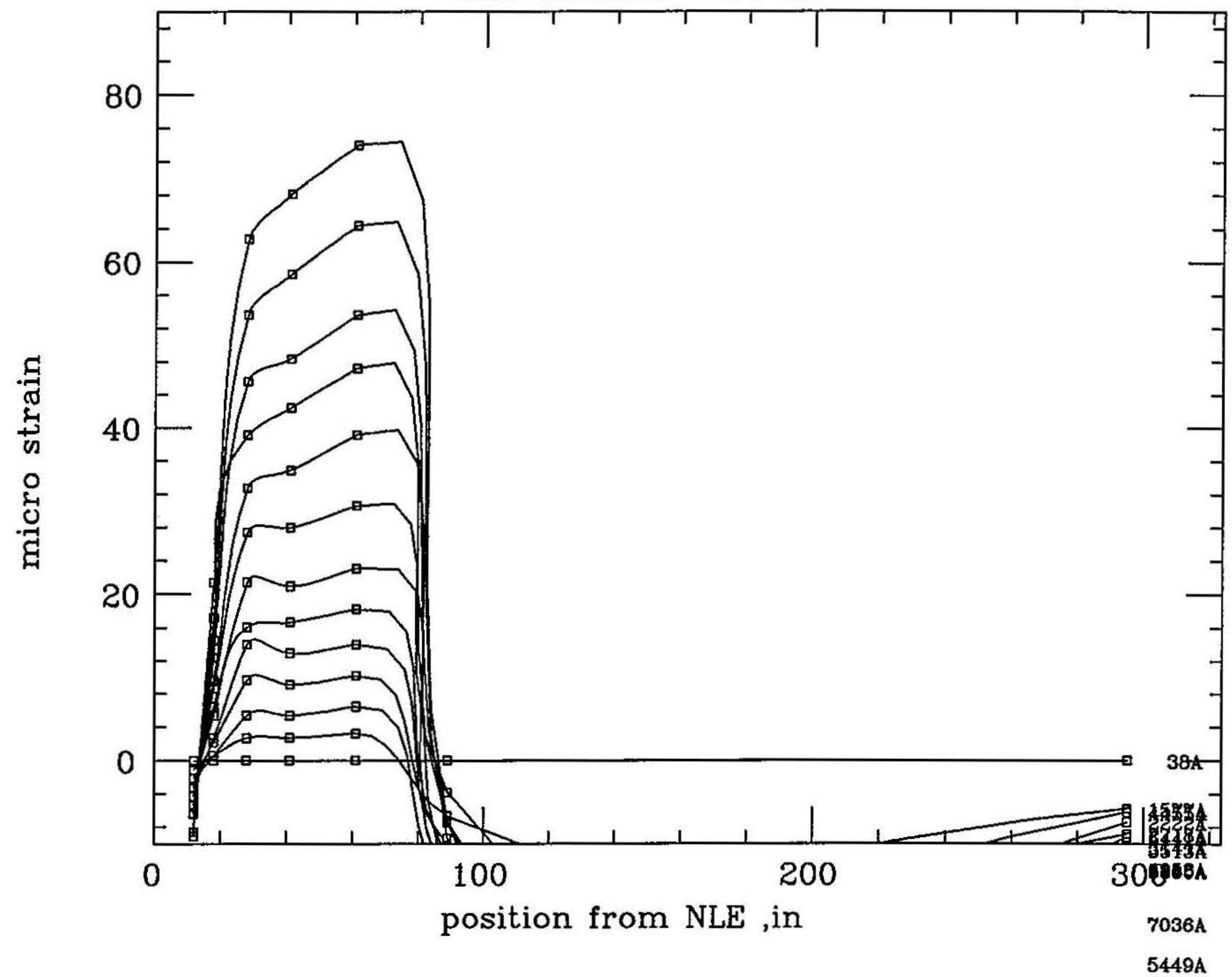
DCA313 E–M axial strain



CA008

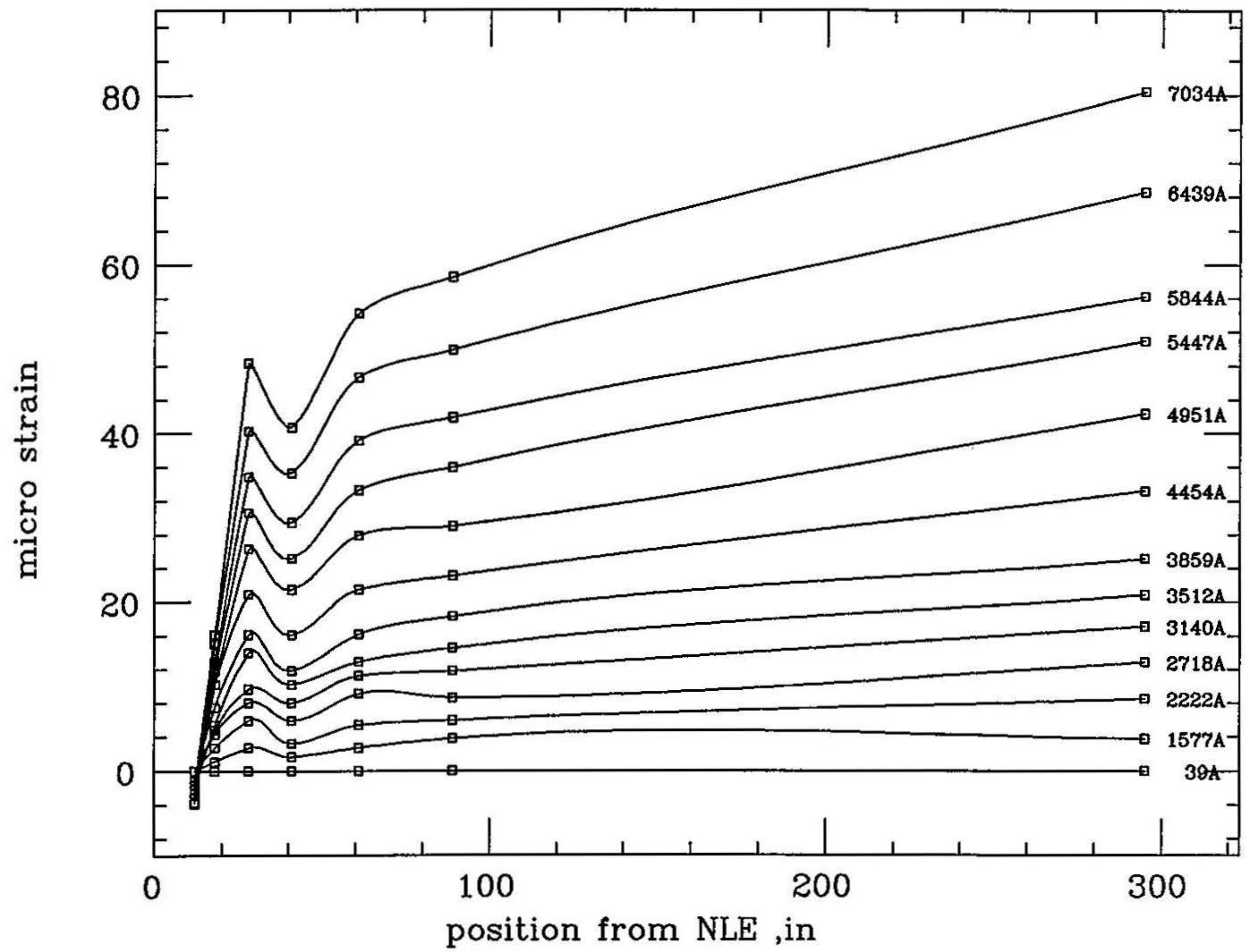
DCA314 E–M axial strain

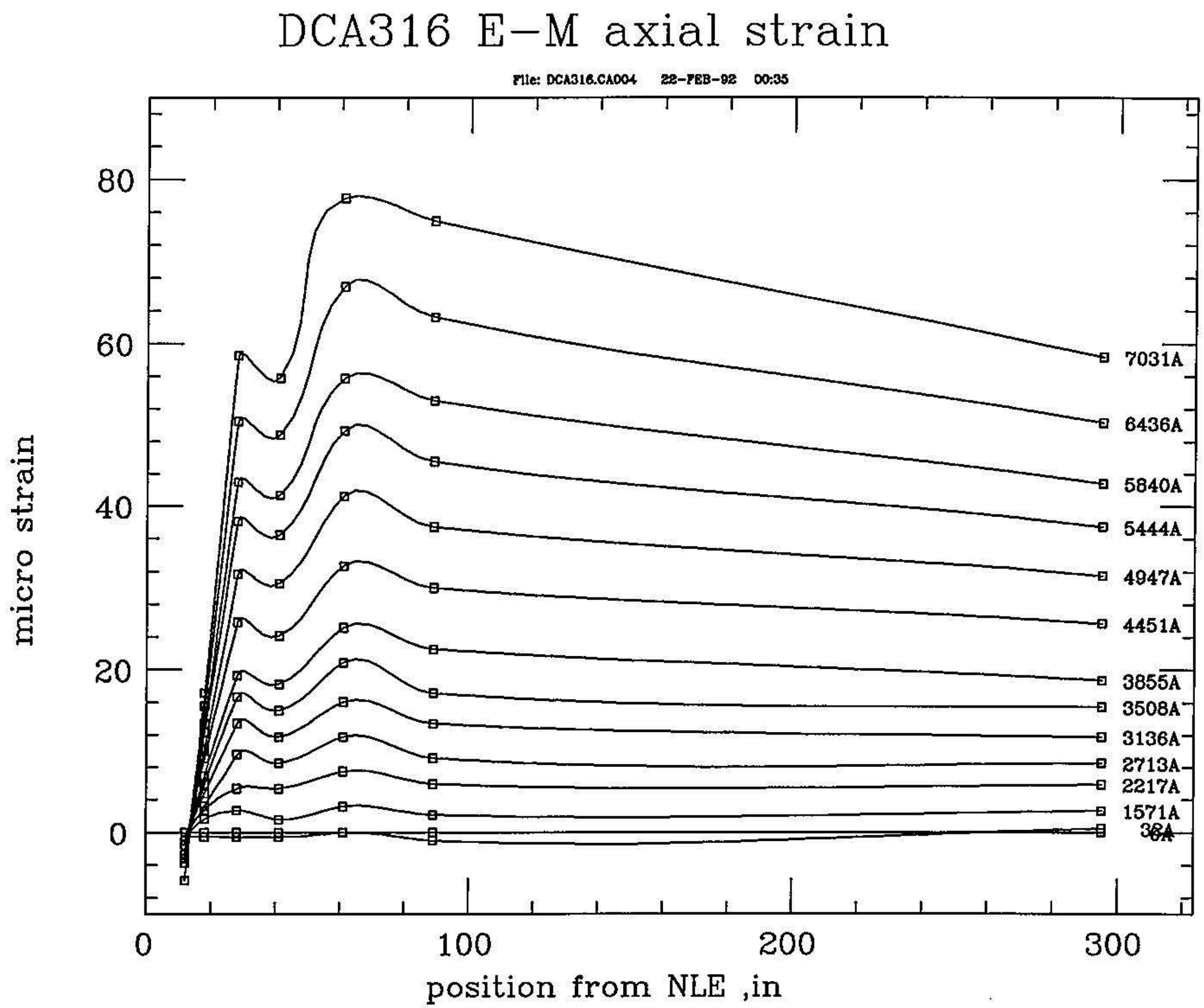
DCA314 File: DCA314.CA008 4-FEB-92 00:18



C0012

DCA315 E-M axial strain





DCA316 E−M axial strain
File: DCA316.CA004 22-FEB-92 00:35
micro strain
position from NLE ,in
0
20
40
60
80
100
200
300
7031A
6436A
5840A
5444A
4947A
4451A
3855A
3508A
3136A
2713A
2217A
1571A
36A
6A