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Overtensioning of Wires as an Alternative to Prestressing the Drift Chamber Endplate

Abstract

It has been proposed that instead of prestressing the chamber endplate (with an intrusive mechanical device), the chamber might be strung with wires overtensioned by amounts such that the endplates relax to the desired shape as stringing progresses. We use the analytic stress calculation described in note Princeton/BaBar/TNDC-96-41 to predict the required overtensioning.

1 Method

The calculation proceeds in several steps:

1. Calculate the desired final displacements $z_F(r)$ of both endplates.
2. Calculate the present displacement $z_P(r)$ of the endplates at the time a wire is strung at radius R, assuming all wires at $r < R$ have already been strung. Record the displacement of the plate at the position of the wire being strung: let $z_S(R) = z_P(R)$.
3. Use the difference between the actual and desired displacement of the endplate to calculate the (over)tension of the next wire to be strung.
4. Calculate the relaxation in tension of wires already strung at radius $r < R$ due to the difference between the present position of the endplate, $z_P(r)$, and the position $z_S(r)$ when the wires were strung.
5. Go to step 2 and process the next wire.

The calculations of steps 1 and 2 are done with the analytic stress analysis described in note Princeton/BaBar/TNDC-96-41. The tensions in the wires already strung are needed as input.

In step 3 we use the desired final displacement z_F and the present displacement z_P of the endplate at the position of the next wire to be strung to calculate the overtension S that will later relax to the desired final tension T. The present displacement z_P is smaller than the final displacement z_F because not all wires have been strung yet; as more and more are strung z_P will increase to z_F, so the wires contract and the tension drops. Thus $S > T$ as implied above.

The tension S as we string the wire is related by

$$S = EA\frac{\Delta l}{l} = EA\frac{\Delta l}{z_C - z_P - \Delta l},$$

where E is the Young's modulus of the wire, A is the area of the wire and z_C is the length of the chamber. The denominator is the length of the wire before stretching. For brevity, we let z_P represent the sum of the displacements of the two endplates.[1] Hence

$$\Delta l = \frac{S}{S + EA}(z_C - z_P).$$

Now the difference, $S - T$, between the tension as strung and the final tension should be just enough to cause the wire to stretch by the difference $z_F - z_P$ between the desired final displacement and the present displacement:

$$S - T = EA\frac{z_F - z_P}{z_C - z_P - \Delta l},$$

where again we use the unstretched length of the wire in the denominator. Inserting our expression for Δl we find the overtension to be

$$S = T\frac{z_C - z_P}{z_C - z_F} + EA\frac{z_F - z_P}{z_C - z_F}.$$

In step 4 we need to calculate the present tension S' in a wire that we installed at tension S. These are different because the endplate deforms as more wires are installed. The expression for S' in terms of S is exactly the same as that for S in terms on T on substituting the displacement z_S when the wire was strung for the final displacement z_F:

$$S' = S\frac{z_C - z_P}{z_C - z_S} + EA\frac{z_S - z_P}{z_C - z_S}.$$

The above procedure is implemented in a FORTRAN program `prestress.for` that is available in the Princeton Technical Notes Web page. The program iterates one wire layer at a time, rather than one wire at a time.

2 Results

Table 1 summarizes the calculation for overtensioning of wires in a chamber 2.764 m long with a 24-mm-thick rear endplate and a 14-mm-thick front endplate (with no step). Both endplates are simply supported at the inner and outer radii. The desired wire tensions are 34, 86 and 182 gm for the sense, clearing and field wires, respectively.

[1] z_P should also include the displacement of the inner and outer support cylinders under compression. This small effect may be added in a later analysis. Also, the area A of the wire is reduced slightly as the wire is stretched; $\Delta A/A = -2\nu\Delta l/l$ where ν is Poisson's ratio. We have neglected this small correction for now.

Table 1: Summary of wire overtensions.

Layer	Front Deflection (mm)	Rear Deflection (mm)	No. of Sense Wires	Tension (gm)	No. of Clear Wires	Tension (gm)	No. of Field Wires	Tension (gm)
1	0.296	0.059	96	35.5	192	90.6	288	192.4
2	0.448	0.089	96	36.2	0	92.9	192	197.6
3	0.587	0.116	96	36.9	0	95.0	192	202.3
4	0.720	0.143	96	37.5	192	97.0	192	206.7
5	0.962	0.191	112	38.6	224	100.5	224	214.6
6	1.081	0.214	112	39.1	0	101.9	224	217.8
7	1.192	0.237	112	39.5	0	103.3	224	220.9
8	1.296	0.257	112	39.9	224	104.5	224	223.5
9	1.433	0.285	128	40.3	256	105.9	256	226.7
10	1.521	0.302	128	40.4	0	106.3	256	227.7
11	1.601	0.318	128	40.6	0	106.9	256	229.0
12	1.673	0.332	128	40.7	256	107.2	256	229.8
13	1.763	0.350	144	40.8	288	107.5	288	230.3
14	1.816	0.360	144	40.7	0	107.0	288	229.3
15	1.861	0.369	144	40.6	0	106.8	288	228.9
16	1.898	0.377	144	40.5	288	106.5	288	228.1
17	1.947	0.387	176	40.3	352	106.0	352	227.0
18	1.962	0.389	176	39.9	0	104.7	352	224.0
19	1.969	0.391	176	39.7	0	103.9	352	222.2
20	1.967	0.390	176	39.4	352	102.9	352	220.1
21	1.951	0.387	192	38.9	384	101.5	384	216.9
22	1.931	0.383	192	38.4	0	100.0	384	213.5
23	1.903	0.378	192	38.1	0	99.0	384	211.2
24	1.868	0.371	192	37.8	384	97.9	384	208.8
25	1.805	0.358	208	37.3	416	96.4	416	205.4
26	1.753	0.348	208	36.8	0	94.9	416	202.1
27	1.693	0.336	208	36.5	0	94.0	416	200.0
28	1.628	0.323	208	36.2	416	93.1	416	197.9
29	1.487	0.295	224	35.8	448	91.6	448	194.7
30	1.405	0.279	224	35.4	0	90.5	448	192.2
31	1.319	0.262	224	35.2	0	89.9	448	190.7
32	1.227	0.244	224	35.0	448	89.2	448	189.1
33	1.088	0.216	240	34.7	480	88.3	480	187.1
34	0.986	0.196	240	34.5	0	87.6	480	185.7
35	0.881	0.175	240	34.4	0	87.2	480	184.8
36	0.772	0.153	240	34.3	480	86.9	480	184.0
37	0.612	0.122	256	34.2	512	86.5	512	183.1
38	0.497	0.099	256	34.1	0	86.2	512	182.5
39	0.381	0.076	256	34.0	0	86.1	512	182.3
40	0.256	0.051	256	34.0	512	86.0	768	182.1