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Estimation of Small Geometry Deviation for TESLA-Shape Cavities due to Inner Surface Polishing

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Abstract

Two well-known polishing methods are used for the inner surface cleaning of superconducting TESLA-shape cavities [1]: electro-polishing (EP) or buffered chemical polishing (BCP). The amount of removed material is relatively small and varies from 5 till 140 μm. The cavity is closed after polishing to prevent scratches or dust appearing on its inner surface. The estimation of the removed material amount is possible by different criteria, for example by comparison of weight before and after cleaning, or by the time - cleaning procedure duration. Both calculations could give us only approximate average value of the removed material amount.

We describe the method for estimation of small geometry deviation basing on RF frequency measurements, which allows calculation of the different influence of surface treatment on the iris and equator areas

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Some RF characteristics, like frequencies (Fo and Fpi), are very sensitive to geometry deviations. For radius changes at iris (Ri) and equator (Re) areas *calculated* values are:

$$\begin{bmatrix} dFo \\ dFpi \end{bmatrix} = S \begin{bmatrix} dRi \\ dRe \end{bmatrix}, \qquad (1)$$

where $S = \begin{bmatrix} \mathbf{0.413} & \mathbf{-14.572} \\ \mathbf{3.996} & \mathbf{-14.623} \end{bmatrix}$ MHz/mm.

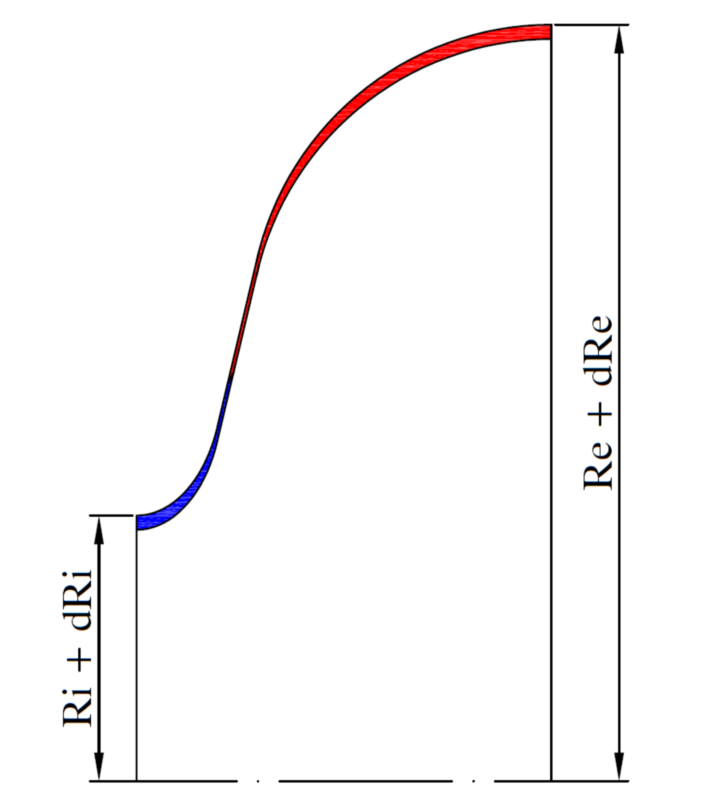
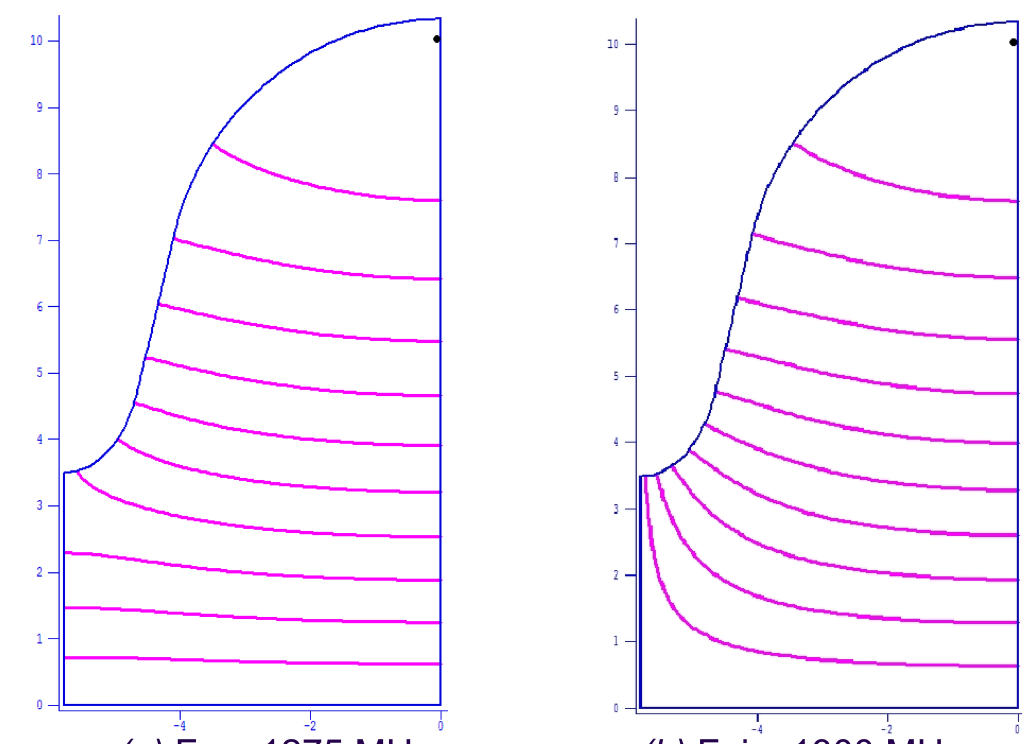


Figure 1: Radius deviations at iris (dRi) and equator (dRe) areas



(a) Fo ≈ 1275 MHz *(b) Fpi ≈ 1300 MHz*

Figure 2: TM010 E-Field distribution for zero (a) and pi-mode (b)

Even small radius changes (about a few μm) can be found basing on the *measured* data of frequency changes, using:

$$\begin{bmatrix} dRi \\ dRe \end{bmatrix} = A \begin{bmatrix} dFo \\ dFpi \end{bmatrix}, \qquad (2)$$

where $A = \begin{bmatrix} \mathbf{-280.19} & \mathbf{279.20} \\ \mathbf{-76.56} & \mathbf{7.91} \end{bmatrix}$ μm/MHz.

Parameters	Units	Cavities after BCP								
		CAV00500	CAV00506	CAV00516	CAV00516	AC151	AC152	AC155	AC155	AC155
Date		22.11.2012	08.10.2012	25.06.2013	27.06.2013	15.05.2012	25.05.2009	26.05.2010	03.04.2012	11.06.2012
Fo (before BCP)	MHz	1275.024	1275.206	1272.839	1272.839	1274.792	1271.613	1273.227	1274.983	1274.891
Fo (after BCP)	MHz	1274.763	1275.074	1272.620	1272.714	1274.710	1269.883	1272.920	1274.891	1274.118
Fpi (before BCP)	MHz	1299.686	1299.765	1297.765	1297.710	1299.685	1296.809	1297.520	1299.622	1299.553
Fpi (after BCP)	MHz	1299.518	1299.680	1297.574	1297.615	1299.628	1295.688	1297.308	1299.553	1299.052
dFo	MHz	-0.261	-0.132	-0.219	-0.125	-0.082	-1.730	-0.307	-0.092	-0.773
dFpi	MHz	-0.168	-0.085	-0.191	-0.095	-0.057	-1.121	-0.212	-0.069	-0.501
BCP (from TESLA DB)	μm	**20**	**15**	**10**	**10**	**5**	**>10 +100**	**20**	**8**	**50**
|dFpi| / 10 (kHz/mm)	μm	21	-9	-19	-10	-6	-112	-21	-7	-50
dR iris	μm	**26**	**13**	**8**	**8**	**7**	**172**	**27**	**7**	**77**
dR equator	μm	**19**	**9**	**15**	**9**	**6**	**124**	**22**	**6**	**55**
dRe / dRi	%	71	71	190	104	83	72	81	100	72
Comments		2 x cold	2 x cold			2 x cold	2 x CTM	2 x CTM?	2 x cold	2 x cold

Parameters	Units	Cavities after EP										
		CAV00500	AC151	AC152	AC153	AC153	AC155	AC116	CAV00001	CAV00002	AC114	AC114
Date		21-28. 02.2012	31.05.2011 15.11.2011	17.11.2011	06.12.2010	09.05.2011	14.03.2011	14-16. 01.2008	02-06. 12.2011	07-09. 12.2011	18.07 - 01.08.2007	29.10.2007
Fo (before EP)	MHz	1274.590	1272.644	1274.486	1272.551	1272.582	1273.305	1273.455	1276.431	1276.710	1273.176	1272.740
Fo (after EP)	MHz	1272.588	1272.341	1274.373	1271.949	1271.969	1272.687	1272.143	1275.294	1275.636	1272.776	1272.338
Fpi (before EP)	MHz	1298.817	1297.350	1299.638	1297.315	1297.607	1297.650	1297.838	1299.706	1299.865	1297.563	1297.308
Fpi (after EP)	MHz	1297.531	1297.198	1299.573	1296.977	1297.267	1297.284	1297.052	1299.037	1299.238	1297.317	1297.071
dFo	MHz	-2.002	-0.303	-0.113	-0.602	-0.613	-0.618	-1.312	-1.137	-1.074	-0.400	-0.402
dFpi	MHz	-1.286	-0.152	-0.065	-0.338	-0.340	-0.366	-0.786	-0.669	-0.627	-0.246	-0.237
EP (from TESLA DB)	μm	**96+72+10**	**12+12**	**12**	**13+48**	**48**	**48**	**90+50+10**	**72+48+10**	**72+48+10**	**12+12+24**	**48**
|dFpi| / 8 (kHz/mm)	μm	161	19	8	42	42	46	98	84	78	31	30
dR iris	μm	**202**	**42**	**14**	**74**	**77**	**71**	**148**	**132**	**126**	**43**	**46**
dR equator	μm	**143**	**22**	**8**	**43**	**44**	**44**	**94**	**82**	**77**	**29**	**29**
dRe / dRi	%	71	52	60	58	58	63	64	62	61	66	62
Comments		2 x CTM	2 x CTM	2 x cold	2 x CTM	2 x CTM	2 x CTM	2 x CTM	2 x CTM	2 x CTM	2 x CTM	2 x CTM

Limitations

- Sensitivity matrixes S and A are found for TESLA – shape cavities (with Ri = 35 mm, Re = 103.3 mm) and cannot be used for another geometries without corresponding corrections.
- Equation (2) can be used, if frequency changes dFo and dFpi are caused only by radius increase (due to surface polishing). Influences of others factors, like temperature or cavity filling, have to be excluded or strongly reduced.
- This method is based on the assumption that all changes are identical for all cavity cells. No other deformations, like elongations or eccentricity changes, are taking place.

Summary

- The method, based on RF measurement results, is being used successfully at DESY for 15 years.
- The most important aspects are:
  - it has a good correlation with other estimations of removed material for both inner surface polishing processes: BCP and EP;
  - it can be used in a “wide” range of radius changes: from 5 μm till 200 μm;
  - it allows us estimation of not only the average value of removed material from the cavity surface, but also for different regions: iris and equator areas.

Referencies:

1. D. Proch, “The TESLA Cavity: Design Considerations and RF Properties”, Proceedings of the Sixth Workshop on RF Superconductivity, SRF93, CEBAF, Newport News, Virginia, USA, 1993, p.382
2. J. Sekutowicz, “2D FEM Code with Third Order Approximation for RF Cavity Computation”, Proceed. Linear Accelerator Conference, Tsukuba, Japan, 1994, p. 284
3. http://tesla-new.desy.de/cavity_database/summaries/

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