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Disk characteristics of H60VG4SL17-A,B

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Abstract

The primary aim of the two-fold interleaved structures, H60VG4SL17-A,B, is the proof of the long-range wake field of the interleaved structure design. We have made the constituent disks trying to make them to fit well to the target. The qualification of the disks is the main issue of the present paper. In addition to the information related to the wake field, these structures are to be tested in high power. In this respect, we obtained some advanced understandings to make the HDDS disks from the high-field point of view. Those issues are also described in this paper.

1. Introduction

The wake field suppression of the accelerator structures of the main linac for GLC/NLC is one of the main issues to preserve the low emittance through the linac. Prototype structures such as DS1, M2, DDS1, DDS3 and RDDS1 have served to prove the feasibility of the calculation of the wake field in detuned or damped-detuned structures. Especially in the last one, 1.8m-long RDDS1, all of the cells were well controlled in HOM frequencies so that the measured wake field was proved to be consistent to that calculated based on the measured frequency distributions.[1]

While the wake field suppression was proved in those structures, their high field operation showed frequent breakdowns and those breakdowns caused severe frequency change in the accelerating mode, which is not allowed to use for 10-20 year operation. To operate at a high field with less breakdowns and less frequency shift, the structure design has evolved to cite higher phase advance with smaller group velocity resulting in the shorter structure length, 60cm. These structure is called HDDS, high-phase-advance damped-detuned structure.

Since the structure consists of only 55 cells, the wake field suppression during the long beam pulse period makes it necessary to interleave the structure in four fold. The present structures, called SL17-A,B here, are the two-fold interleaved structures which are dedicated as test structures to prove the interleaving mechanism and the calculation method. For this end, the cells should be well controlled in HOM frequencies. We applied the diamond turning to make these disks to form the cells of the structure. The absolute values of their accelerating mode frequencies should be well close the nominal one so that no tuning (or not big tuning) is needed. This makes the HOM frequencies directly determined by the machining itself. The quality of the smoothness of HOM frequency necessary for wake field suppression is confirmed by measuring the pseudo-accelerating mode frequency in the single-disk frequency checking.

In addition to these wake field related requirements, the disks were carefully made to assure their high field performance. Special cares are on the ridges, which appear between turned surface and milled one.

The disks for the present structures were made taking care of these issues. We review in this note the record of the disk fabrication in such respects to serve for the information of later wake field measurement and the high power test.

2. Design parameters

The shape of the cells of the present structures is the same as the previous HDDS disks. Because the present disks are for interleaved structures so that the smoothness are important, we designed the actual disk dimensions to make the cell frequency as close as the nominal so that we do not need to tune after bonding. To this end, we measured 5 identical test disks so that we measure the absolute frequency inherent to them and applied the feedback to the dimensional correction to the actual disks. The KEK drawing numbers, which we should refer to, in case we need to know the actual design parameters, are given below.

1. HDDS5-1999-034-00	Dimensions of standard disk
2. HDDS5-1001-034-00	Standard disk
3. HDDS5-1005-034-00	Disk 02
4. HDDS5-1006-034-00	Cup 02
5. HDDS5-1007-034-00	Cup 52

The original dimensional parameters of these structures were given by from SLAC.[2] Parameters such as “2a”, “2b” and “t” which determines the cell frequency and “h” and “W3” are shown in Fig. 1. These are interleaved with type A and B as shown in Fig. 2, which shows the middle of the structure. Here the disks of structure “A” are numbered in integers while those of “B” in half integers. As intuitively understood from the sensitivity of these dimensions to frequencies, it is a sure method to keep the dimensional tolerance of 2 microns in the turned areas and 10 microns in the milled areas. More precise tolerance determination process is described in the later paragraph in this chapter.

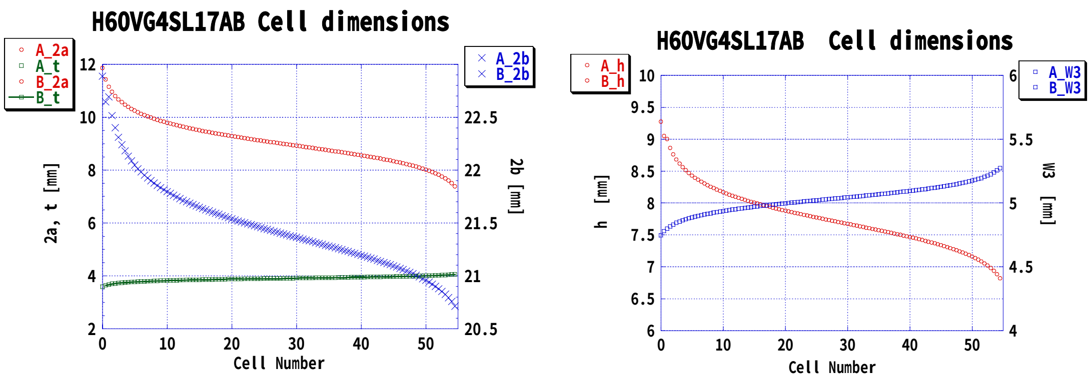


Fig. 1 Cell dimensions.

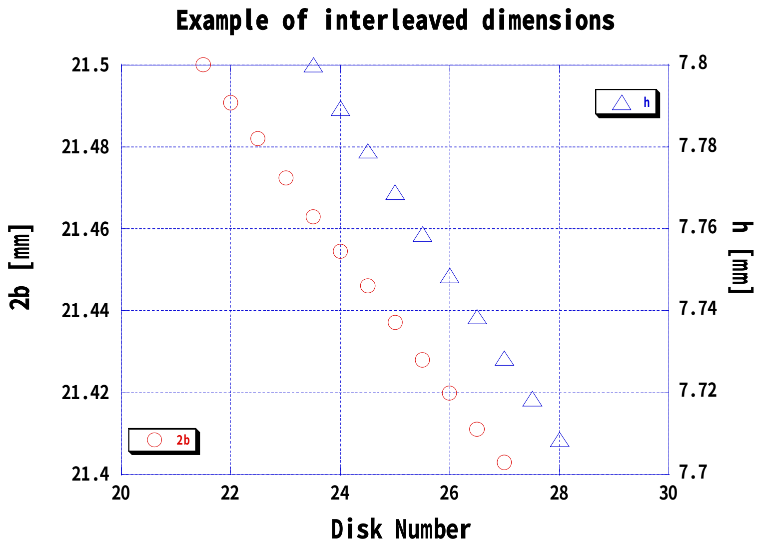


Fig. 2 Typical disk parameters of the present interleaved structures.

These structures are to be tested in high power after wake field measurement. Therefore, various surface qualities should be realized. Smooth connection between turned surface and milled one is one of such issues. To assure a good connection between the milled R2mm wall and the turned “b” cylinder, the milled part is shifted away from the beam axis by 10 microns. The actual connection from this milled surface to turned “b” surface is given in the radius of 9mm, close to “b”. This 10-micron shift makes the frequency lower than the nominal without the offset so that we put an offset value of -5 microns in “b” in all of the disks. This smaller value in “b” than the position offset reflects to the fact that the cell is not completely surrounded by turned surface but nearly half of the cylinder is open toward manifold. Many parameters such as “h”, HOM position etc. are related to “b” and we designed to change all of these values related to “b” change. Here we keep such parameters “b-h”, the separation between “b” and slot turning point “h”, and “C/2-b” the separation from “b” to manifold in order to keep the higher-mode characteristics the same as original.

Tolerance of some of the milled parts were made severe for satisfying the HOM frequency performance and sometimes to keep the connection between turned surface and milled one as shown by the arrows in

Fig. 3, which is a part of the standard disk drawing. The periphery tolerance of the milled areas, which determine the resonant frequency, is set 10 microns.

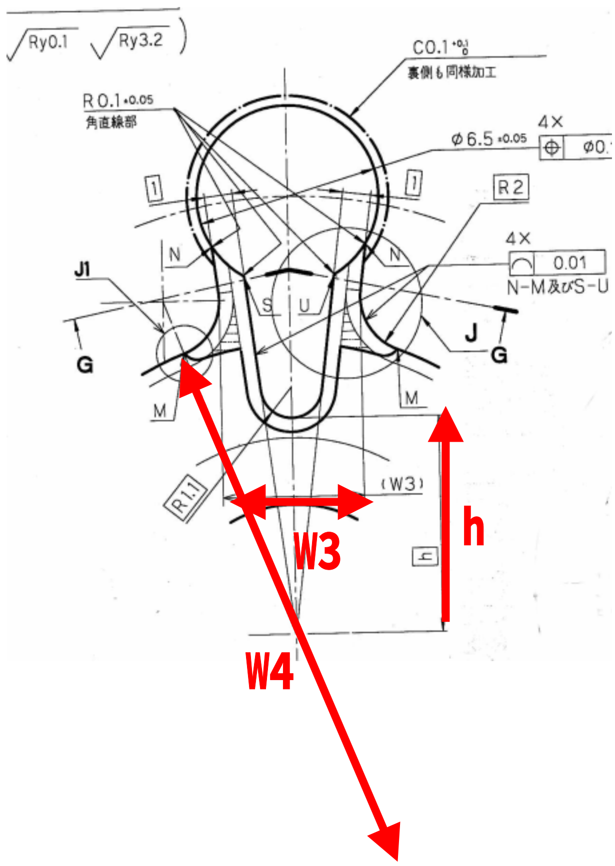


Fig. 3 3D milling slot shape of standard disk.

Based on the experience of the preceding structures, the dimensional parameter corrections applied to the recent structures were listed in the following table. The structure of this paper is item 5. The δb of -5 microns was applied with respect to those specified by SLAC original parameter set with associated dimensional changes keeping the HOM coupling parameters unchanged with modified “b” dimension.

The reason of the offset is as follows. Comparing to the SLAC original design parameters, we located the milled rounded part with 2mm in radius to be set back outer ward by 5 microns, making “W4” in Fig. 3 by 10 microns larger. By this shift, we estimate –4MHz in frequency. However, we observed –6MHz in the previous structures with this shift. Since the mechanism of the difference of 2MHz is not understood, we firstly set “δb” (but “δb” only) by –5 micron to make +4MHz correction. This amount is estimated as 1.2MHz/micron X 5 microns X 0.7, while the last factor is assumed to take into account of the actual “δb” area without any effect at the opening between cell and HOM manifold where “W3” stands. Because this design still gave us–2MHz from the nominal value, we decided to make "δb" correction with all other parameters shifted related to the change of "b" value for the present structure fabrication.

Table 1. Dimensional corrections from SLAC original design parameters.

	Structure	Aim	Test at	δb (μm)	Related corrections
1	H60VG4S17-I Test	Fab. Test	KEK	0	-
2	H60VG4S17-I	High power	SLAC	-5	No (b only)
3	H60VG4S17-II	High power	SLAC	-5	No (b only)
4	H60VG4SL17-A,B Test	Fab. Test	KEK	-5	Yes
5	H60VG4SL17-A,B	Wake field	SLAC	-5	Yes
6	H60VG4S17-III(1,2)	High power	SLAC	-5	No (b only)
7	KX02	High power	KEK	-5	No (b only)

Sensitivities of frequencies to dimensions

We are aiming at the wake field study of the interleaved structures, while keeping the basic characteristics needed for high power evaluation. In order to fulfill the requirement for the former (wake field) study, the lowest dipole mode frequencies are to be distributed close to the design values with keeping the smoothness of the frequencies from a cell to the next. The distribution can be deviated from the ideal one by say 10 MHz or so but the cell-to-cell smoothness should be within 1 MHz or so.

In order to estimate the mechanical tolerance of the cell production, the sensitivities of frequencies to dimensional errors are calculated and listed in the Table 1. The parameters, "a" and "b" are the radius of beam hole and the cell, respectively. The parameter "W3" is the width of the channel from cell to manifold as shown in Fig. 3. Estimating from these values, we concluded that the tolerable dimensional errors in cell fabrication could be about 1-2 microns for cylindrical shape while those of 3D milling parts within 10 microns or so. This required level is within that we have already established.

When the cells are made within this level of precision, we tune the fundamental frequencies by cell tuning mechanism, feed-forward correction[3] or by operational temperature. In either case, we can precisely tune the accelerator mode frequency well, or in other word the accelerator mode phase advance kept along the structure, while keeping the dipole mode frequency smoothness because the amount of the correction is as small as 1-2 MHz.

Table 1. Frequency sensitivity to dimensions.

Mode		f_0				f_1		
Phase advance		0	$1/2\ \pi$	$5/6\ \pi$	π	0	$1/2\ \pi$	π
Frequency	MHz	11093	11265	11411	11435	16122		15107
Sensitivity	MHz/μm							
$\partial f / \partial a$				0.39		0.14		-0.35
$\partial f / \partial b$				-1.2		-1.52		-1.23
$\partial f / \partial W3$				-0.13		-0.17		-0.13
$\partial f / \partial W4$				-0.4				

3. Fabrication flow

Fabrication flow

We changed various processes of the disk fabrication comparing to the precious structures, such as that described for the H60VG3S18[1]. Following is the rough description of the present fabrication flow.

1. Cut disk from bar stock
2. Rough turning with 0.2mm undercut
3. Boring tuning holes and engraving numbering
4. Turning cup side and disk side (leaving 20μm for KEK turning)
   except for both end surfaces where undercut amount of 10 μm for the vendor
   in addition to KEK's final cut of 20μm
5. Measurement of relevant dimensions
6. Milling cup side including HOM manifolds and slots
7. Milling disk side for rounding the slot edge
8. Turning cup-side end surface
9. Turning disk-side end surface and cell inside toward "2a" point

11. Rinsing in an isopropyl-alcohol bath with ultra-sonic vibration
12. Drying by blowing with nitrogen gas
13. Deliver to KEK
14. Inspection by eye and with low magnification microscope
15. Annealing in a hydrogen furnace at 500C for 2 hours
16. Diamond turning of cup side, referring to the milled surface in the cup base,
    where the milled surfaces remain even after this diamond turning.
17. Measure OD
18. Diamond turning of disk side, referring to the end plane of cup side
19. Measure OD
20. Check flatness of both end surfaces
21. Inspection of disk surface appearance, especially around the rounding with R0.5mm
    along the V-shaped slot edge
22. RF inspection on a floating setup
23. Shipping to SLAC

Important changes to be noted are as follows;

1. Annealing is performed after the milling is finished and the amount of turning left for KEK to finish is 10—20 microns. (This is due to the improvement of the vendor's turning performance by applying a better turning lathe.)
2. All relevant turned surfaces are refreshed at KEK with a single-crystal diamond turning. (KEK should be responsible to satisfy the dimensional requirements for HOM control.)
3. Further thorough inspection with microscope in low magnification is applied after final cutting, especially around R0.5mm rounding of slot edge. (We learned more on surface quality every time we made a structure.)
4. The turning lathe was equipped with two tools at the same time so that the initial turning was performed with one of the tools and the finish turning was performed with the better one. (We suffered from tool chipping sometimes due to the surface quality made outside KEK.) This keep the tool for the final cut in its good cutting condition and makes the whole fabrication of the disks of the present two structures without any replacement of the tools.
5. For most of the recovery disks, the nitrogen gas was used for formation of kerosene mist instead of compressed air. (This is a little step toward cutting in a full-nitrogen environment to obtain possibly the better surface.) This was applied only for the fabrication of recovery disks which are mostly numbered as –b or –c. No detectable change was observed in their dimensions nor surface qualities.

4. Mechanical dimensional inspection

Some dimensions were measured for all of the disks, while others were checked in some special disks of measurement use only, which were inserted regularly in the actual disk fabrication. Those of the former are the outside diameters, OD, of the finished disks and milled dimensions such as "h" and "W3," while those of the latter "2a", "2b", "p", "t", "W3" and "W4".

Outside diameter, OD;

The outside diameters of all of the disks were measured as of final diamond turning. This is for ensuring the tool positioning with respect to the machined disk, which determined the important diameters such as "2b" and "2a." The measurement is performed comparing to that of our master disk. The results are listed in the Table 1. Fig. 4 shows those measured after cutting each side of disks. Those (a) as of cup-side are relevant to the dimensions of "2b" and the cup side of "2a," while those (b) as of disk-side the dimensions of disk side of "2a." As shown in these figure is that the outside diameters of machined cups are well within the of +-1 microns, which is much smaller than specified. Standard deviations for both cases are 0.2 micron.

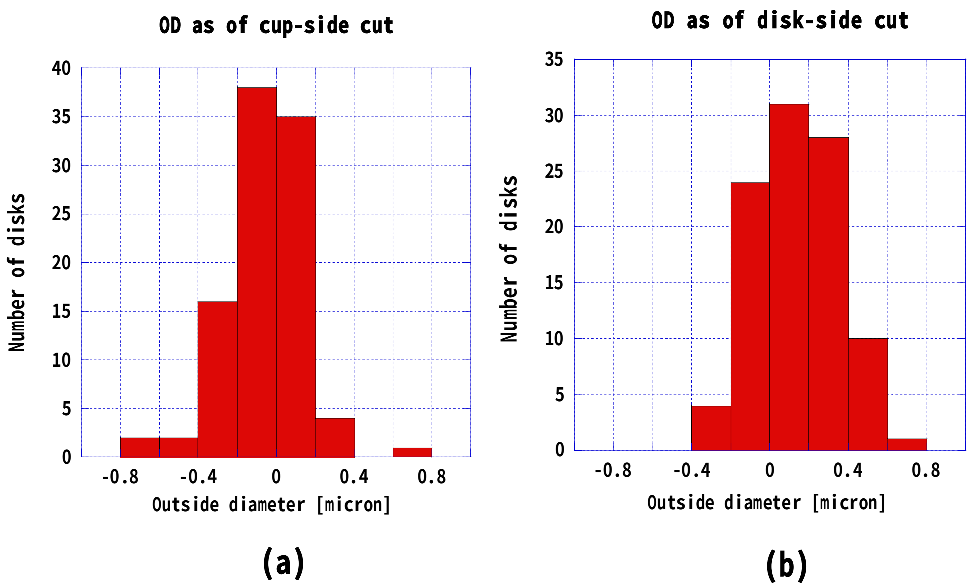


Fig. 4 Outside diameter measured as of finishing each side.

Diameters of disks dedicated for checking dimensions;

Fig. 4 shows the diameters of the measurement-use disks measured by CMM at KEK. We did not apply any offset in CMM measurement so that the absolute values of 2~3 micron off from the nominal values are not our concern. The relative variation of those values is within 1 micron, consistent to the previous measurement shown in Fig. 3(a). From these results, we estimate that there was no unknown error in diameters bigger than 1 micron.

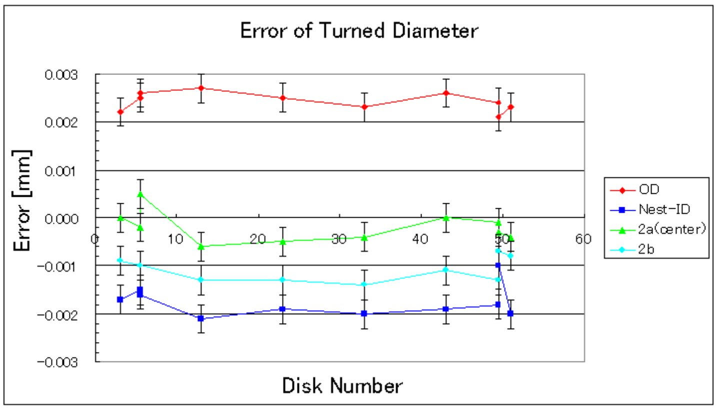


Fig. 5 Diameters measured by CMM.

Thickness of disks dedicated for checking dimensions;

Thickness of disks, "p", and that of thin flat area, "t", are shown in Fig. 5 These are within the tolerance of ±2 microns showing a good turning precision.

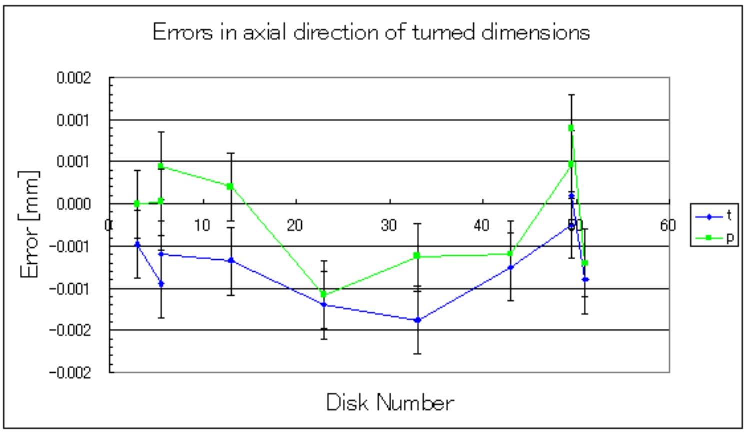


Fig. 6 Thickness measured by CMM at KEK.

Dimensions, W3 and W4;

Two milled dimensions, which deeply affect the frequencies, are W3 and W4. These two parameters are not orthogonal as for the perturbation to frequency but both give us a good measure how well the milled dimensions were controlled. The W3 is the distance between two closely located R2mm milled walls (N—M in Fig. 2) facing each other. The W4 is the distance between the R2mm milled walls but those of facing across the beam axis.

The W3 of all of the disks were measured by the vendor company. The result is shown in Fig. 7 (b) showing a good control of dimensions. Another dimensions "h" are shown in Fig. 6. It is also well controlled.

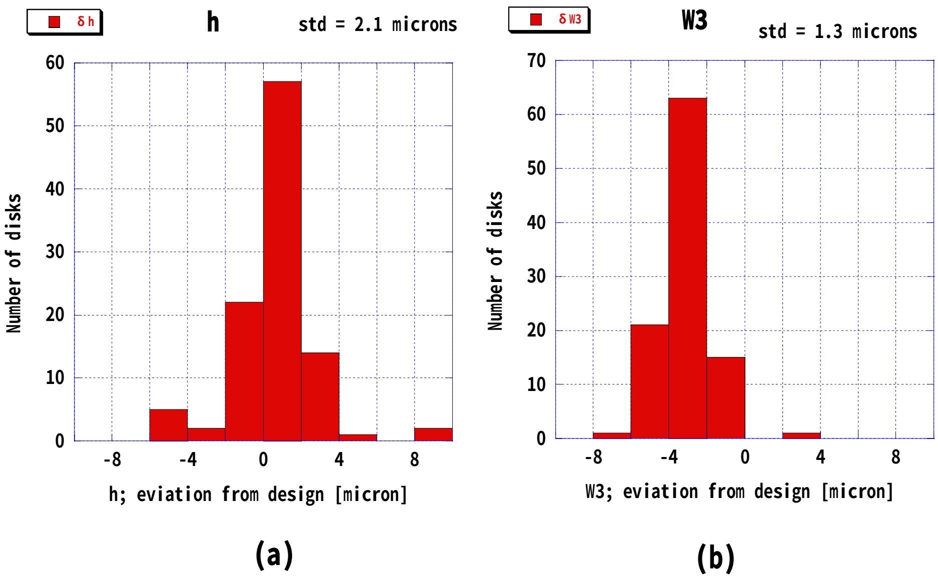


Fig. 7 Milled dimensions, h and W3, measured by vendor company.

Another relevant milled dimension "W4" was measured in addition to "W3" for the disks dedicated for checking dimensions. These were measured at KEK by CMM after final diamond turning. As shown in the figure, the W3 are within the tolerance of ±10 microns, while that of W4 are smaller than the specification of +20micron –0micron. Even though we know the situation of W4 from the beginning, we let the vendor company fabricate as they do and keep their manner throughout the fabrication of disks of these interleaved structures. We concluded that both W3 and W4 are well kept the same throughout the fabrication.

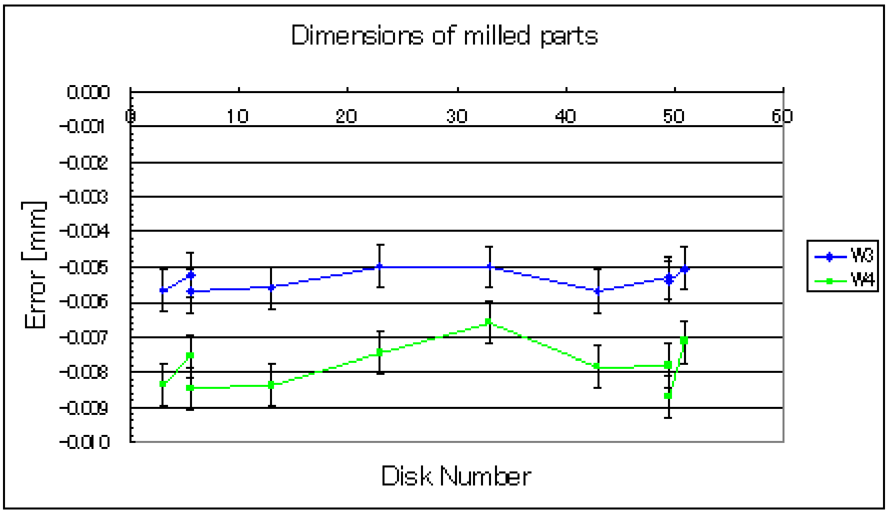


Fig. 8　Milled dimensions measured by CMM at KEK.

Concentricity

Many of milled shapes compose four-fold symmetry around beam axis. Thefore, the radial positions of four parts vary sinusoidally as a function of azimuthal angle if the center is shifted. From the amount of the sinusoidal variation, we measured the concentricity of milled part with respect to the turning. Fig. 8 shows the concentricity of the milled dimensions with respect to the turned part, outside diameter. As shown in the figure, the center of milled shapes is within 7 microns from the center of the turned part.[4]

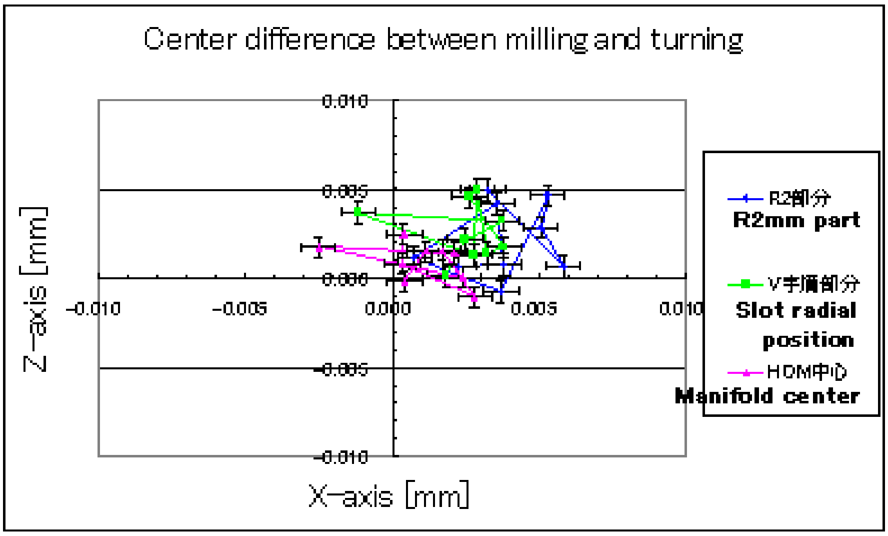


Fig. 9　Shift of milled part w.r.t. turned outside diameter. R2=that of 8 milled parts with radius 2mm, V=that of 4 slot positions where radius=1.1mm and HOM=that of 4 manifolds.

5. RF-QC result

Stack RF-QC for evaluating absolute frequency

Absolute frequency of a periodic boundary condition was observed in a stacked-cell RF QC setup by changing the number of cells. Since the dimensions of the actual cells are obtained at SLAC by interpolating the dimensions of the ideal symmetrical cell shape, the frequency measured in the RF QC setup is not at 11424MHz. This amount can be estimated from the method of interpolation. The absolute frequency can also be evaluated theoretically by using a simulation code "Analyst OM3P." It utilized the linear and quadratic solvers with periodic octant cell models with up to 3.8 million elements and this resulted in an accuracy of 0.5 MHz or better. In the following table 2, the comparison between this calculation and measured values are listed.

The agreement is good and we confirmed that our fabrication of cells gives a precision within 0.5MHz or so, well less than 1MHz.

Table 2　Comparison to between simulation and measurement.

Cell Number	Measurement	Computation	Deviation from calculation
5	11411.7(0.9) MHz	11411.4(0.5) MHz	+0.3　MHz
49	11419.6(0.4) MHz	11420.1(0.5) MHz	-0.5　MHz

Single-disk RF-QC

The measurement for each single disk is shown in Fig. 10. Here the measured values – 10GHz are plotted as a function of design dipole mode frequency.

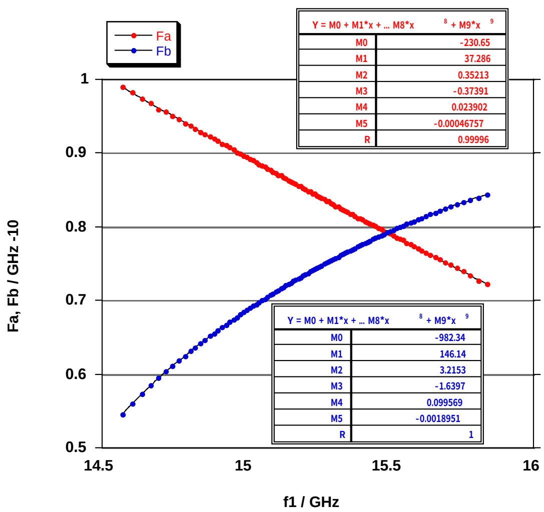


Fig. 10　Single-disk RF QC as function of design F1 frequency.

In Fig. 11 is shown the deviation of the single-disk RF QC frequencies from a polynomial fit up to fifth order applied to those of Fig. 10. Standard deviations of δFa and δFb are 0.6 MHz and 0.2 MHz, respectively. This is well below requirements. The statistical distribution of these errors is plotted in Fig. 12.

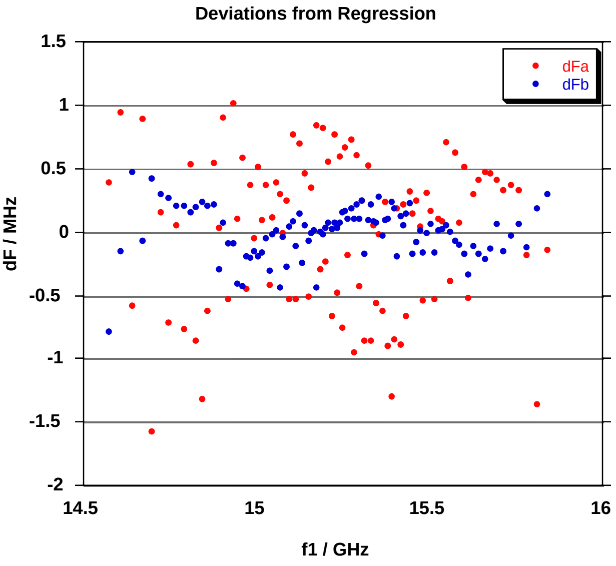


Fig. 11 Deviation of measured single-disk RF-QC from polynomial fitting of fifth order.

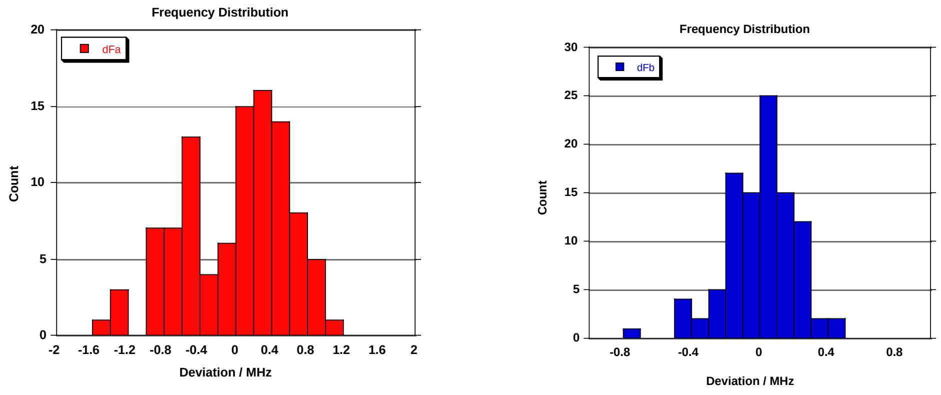


Fig. 12 Statistical distribution of deviation from polynomial fit of Fig. 11.

It is to be noted that the Fb error from the cubic fit shown in Fig. 13 shows a systematic variation by the amount of 1MHz, while no such effect is observed in Fa. It seems that this is inversely related to the similar deviation of the dimension “b” which is seen in Fig. 14 showing the deviation still existing from a polynomial fit up to fourth order.

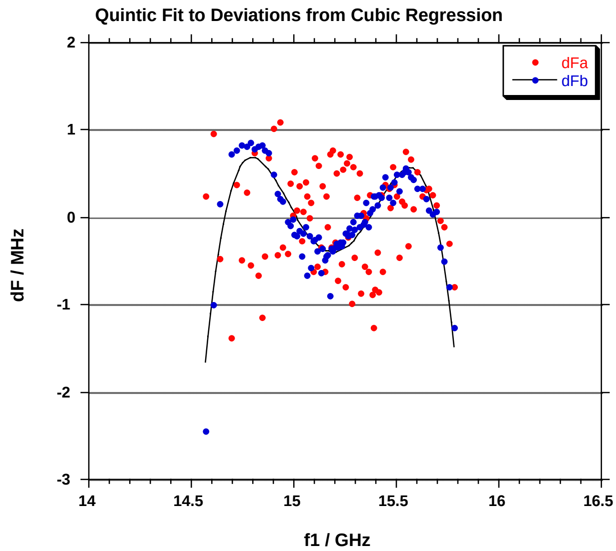


Fig. 13 Deviation of Fa and Fb from cubic fit.

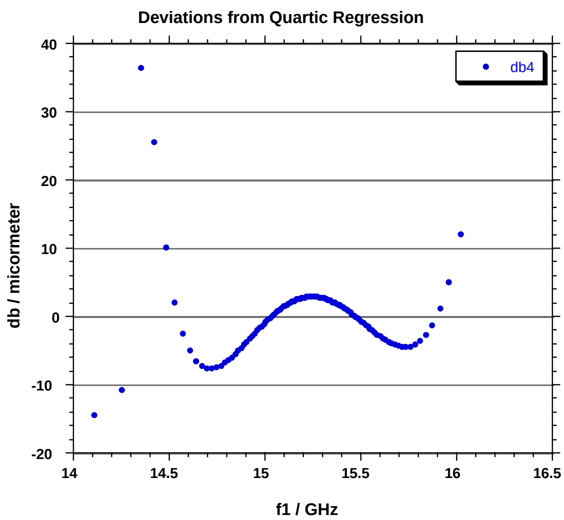
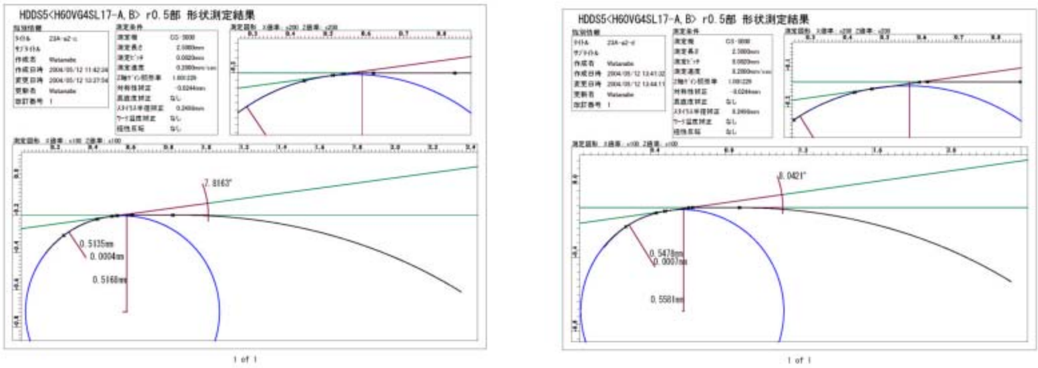


Fig. 14 Deviation of "b" design dimension from a fit with a polynomial up to fifth order as function of F1 frequency.

6. Disk surface quality pursuing better high field performance

Connection angle between R0.5mm and flat surface

The connection between R0.5mm milled surface on the slit and the flat surface was well controlled within a specified angle limit of 12 degrees as shown in Fig. 15　Profile measurement between R0.5mm and flat surface.. This angle is formed by the escape angle of 8 degrees of the milling tool and this agrees to the measured angle.[5]



(a) Cup side　　　　(b) Disk side

Fig. 15　Profile measurement between R0.5mm and flat surface.

Burr between HOM manifold and V-shaped slit

Burrs sometimes appear in the ridge between HOM manifold and slit milled surface as shown in Fig. 16. These burrs were removed by a cotton swab. If not easily removed, such burrs are removed by using sharply cut tungsten wire.

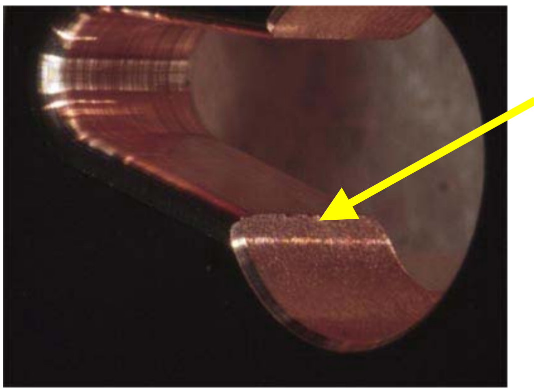
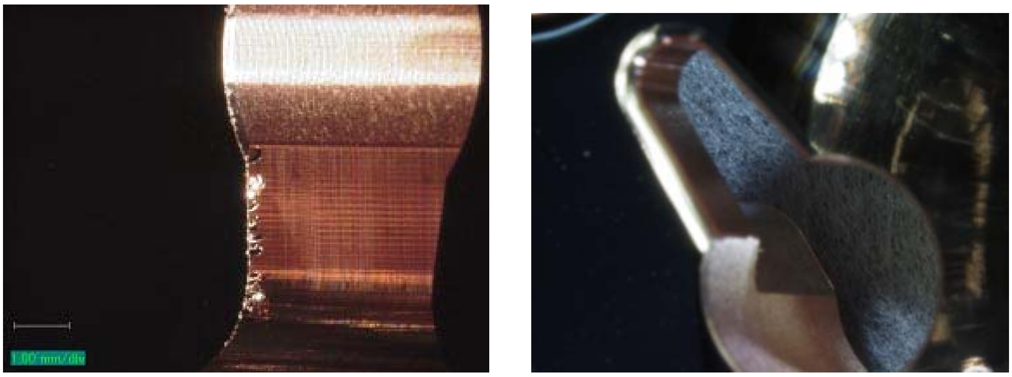


Fig. 16 Burrs on a ridge between HOM and slit.

Burrs of cornice type on R2mm ridge

In early stage, some flaky burrs appeared along the ridge between R2mm milling surface and turning surface in the final turning of our previous H60VG4S17-III structures. Typical appearance is shown in Fig. 17(a). These could easily identified by microscope with a few tens of magnification and we easily removed these with a cotton swab. We routinely check and treated the disks of the present structures in this respect.

Another type of burrs, being big and sticky, have been noticed at the same location in some of the disks as shown in Fig. 17(b) but seen from the other side. Burrs of this type are connected and cannot be removed easily by cotton swab without leaving big deformation. These are formed in the side where the turning tool removes from the work, and very little formed on the other side where the tool comes into work. This difference is seen in Fig. 18. We have not recorded the characteristics of such burrs on the present structures because we have noticed in the fairly late stage of the production. We inspected all of the measurement disks and estimated that such burrs amounts to at most several tens of microns. Typical example of the measurement is shown in Fig. 19 with 0.1mm square mesh pattern for the scale behind. All of the disks were inspected by SLAC and no big cornice-type burrs were identified.[6]



(a) Flaky burrs (seen from cup side) (b) Cornice type (seen from disk side)

Fig. 17 Burrs on R2mm ridge.

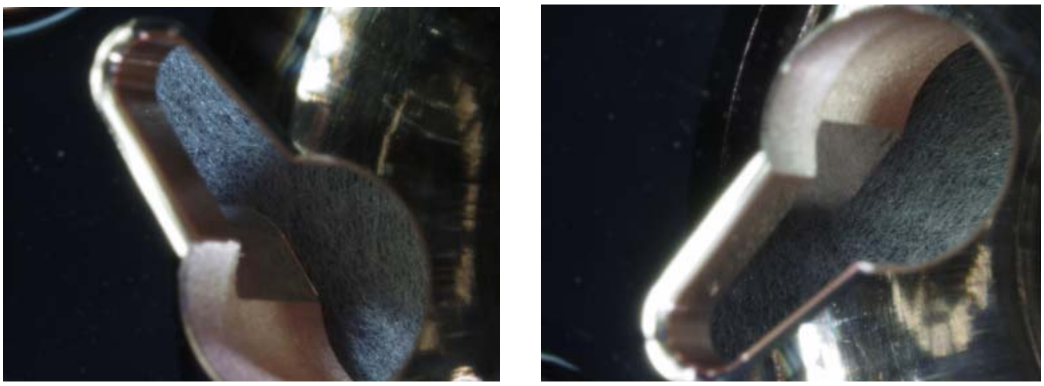


Fig. 18 Two sides of R2mm edge, left with and right without cornice-type burrs.

Fig. 19 Evaluation of size of cornice-type burrs on R2mm ridge with 0.1mm mesh pattern.

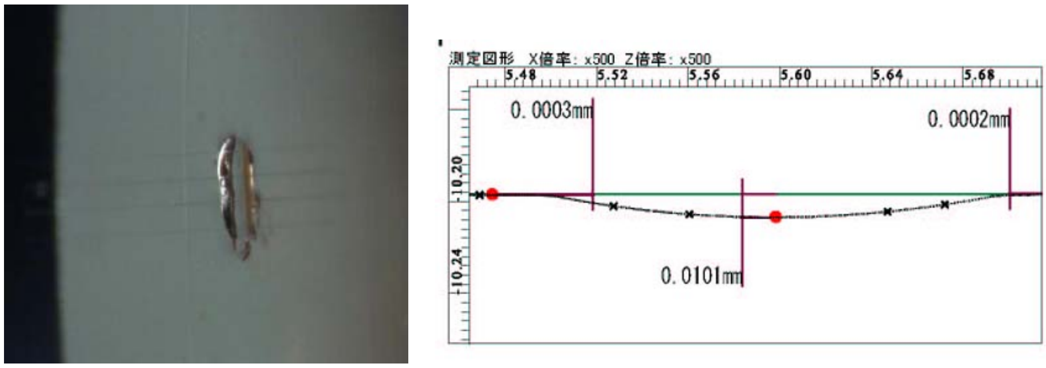
Possible problem: too little cutting amount in final diamond turning

We observed in a few disks, out of all the disks for the two structures, in which rough machined surfaces of the earlier stage remained even after final diamond turning. We determined the amount of our final turning based on the thickness information measured by the vendor company so that we suspect the value from the company but this is not more than one of the possible speculations and we could not identify the mechanism.

From this situation, we are afraid that the final turned surfaces of some of the disks were cut only by a micron or even less, even if they look fine. The final turning at the vendor company was made using poly-crystal diamond tools in an ultra-precision lathe finishing with a cutting amount of a few tens of microns. We should note this possible problem in case these structures behave badly in the high field performance.

Collision of CMM probe in Cup 52B

For standard disks, we did not measure with CMM at all. However, we did for special disks to confirm some relevant RF dimensions. During this process, CMM probe collided on “2b” surface of disk 52B-c in its fast movement mode. Big indentation shown in Fig. 20(a) was created due to this collision. The probe was a sapphire ball with its diameter 0.5mm. The spur of this collision was measured as shown in Fig. 20(b). The straight lines in Fig. 20(a) are those made due to this measurement process. As seen in the (b) profile, we concluded that the collision made an indentation but the shape of the indentation is simple sphere without sharp ridges around the rim. From these we decided to accept this cup.



(a) (b)

Fig. 20 Microscope view of surface at r="b". Light area is cavity inner radius area, while dark area end surface of cup side, (b) Cross-sectional profile of indentation due to collision.

7. Discussions

Wake field issue

We understand that the dipole mode frequencies are well controlled within sigma of 1MHz or so, which is estimated from the smoothness of fundamental frequencies. This is enough for testing the wake field in the two-fold interleaved structures. The actual dipole frequencies of all of the cells were measured at SLAC and the measurement confirmed the well-controlled frequencies[7]. The long-range wakefield of the present two-fold interleaved structures was measured at ASSET of SLAC[8]. The agreement between theory and experiment was very good and this confirmed again the well-controlled frequencies of the cells.

High field issue

The quality of the cells are the best of all recent structures in a sense that the burrs, scratches and connections between two contour shapes are well taken care of based on the experiences of the previous structure cells. Only a few nervous issues are existing and they are all described.

Acknowledgments

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Table 1. Deviation from ideal dimensions. Units are in micron.

	Disk Number	Serial prod. #	OD (as of Cup-side cut)	OD (as of Disk-side cut)	δ 2a	δ 2b	δ t	δ h	δ W3
C02	A	c	??	??		0	-1.4	2	-5
C02	B	b	??	??		-0.3	-1.5	??	??
D02	A	a			2.0		-0.3	??	
D02	B	a			2.4		-0.6	??	
3	A	a	0.0	0.3				0	-3
3	B	a	0.0	0.5				-1	-4
4	A	a	0.2	0.5				-1	-1
4	B	a	-0.4	-0.1				2	-4
5	A	a	0.1	0.5				-1	-1
5	B	a	-0.2	0.2				1	-1
6	A	a	-0.3	0.3				1	-2
6	B	a	0.0	0.3				2	-3
7	A	a	-0.2	0.1				0	-1
7	B	a	-0.2	0.1				1	-4
8	A	a	-0.1	0.2				1	-4
8	B	a	0.0	0.1				0	-3
9	A	a	0.0	0.2				1	-2
9	B	a	-0.3	0.0				-1	-4
10	A	b	0.6	0.0				-5	-4
10	B	a	-0.3	0.1				-2	-5
11	A	a	-0.1	0.3				1	-3
11	B	a	0.1	0.3				1	-5
12	A	b	0.0	0.1				-6	-4
12	B	a	0.1	0.1				1	-5
13	A	a	0.0	0.2				0	-3
13	B	a	0.1	0.3				0	-4
14	A	b	-0.1	0.3				0	-4
14	B	a	0.0	0.3				-2	-4
15	A	a	0.1	0.4				1	-2
15	B	a	-0.1	0.2				1	-6
16	A	b	-0.2	0.2				-5	-4
16	B	a	0.1	0.3				0	-3
17	A	b	-0.2	0.4				-2	-5
17	B	a1	??	??				0	-4
18	A	a	0.0	0.4				1	-2
18	B	a	-0.4	-0.1				1	-4
19	A	a	-0.1	-0.3				-1	-8
19	B	a	0.0	0.0				0	-4
20	A	a	0.0	0.6				-1	-5
20	B	a	-0.1	0.0				-3	-3
21	A	a	0.0	-0.2				-1	-2
21	B	a	-0.3	-0.1				1	-5
22	A	a	-0.2	-0.1				-1	-4
22	B	a	0.0	-0.1				1	-5
23	A	a	-0.2	0.1				-1	-3
23	B	a1	0.0	-0.2				3	-5
24	A	a	-0.1	0.3				0	-2
24	B	a	-0.1	0.4				2	-4
25	A	a	-0.1	0.5				0	-2
25	B	a	-0.1	0.5				0	-6
26	A	a	-0.1	0.3				0	-3
26	B	a	0.0	0.1				-3	-4
27	A	a	0.2	0.1				1	-1
27	B	a	0.1	0.1				2	-4

28	A	a	0.1	0.2			1	-2
28	B	a	0.1	0.1			3	-4
29	A	a	0.1	0.5			-1	-3
29	B	a	-0.2	0.3			-1	-4
30	A	a	0.1	0.3			0	-3
30	B	a	0.0	0.3			2	-4
31	A	a	0.2	0.2			-1	-2
31	B	a	0.3	0.3			2	-4
32	A	a	-0.1	0.1			0	-3
32	B	a	0.1	0.3			0	-3
33	A	a1	-0.1	-0.2			0	-3
33	B	a	-0.2	0.1			-2	-5
34	A	a	-0.4	0.0			-1	-3
34	B	a	-0.8	0.0			1	-5
35	A	a	-0.5	-0.3			1	2
35	B	a	-0.7	-0.1			0	-6
36	A	a	-0.1	0.0			1	-2
36	B	a	-0.3	-0.2			0	-5
37	A	a	-0.2	0.1			2	-4
37	B	b	0.0	0.0			1	-3
38	A	a	-0.5	0.1			0	-4
38	B	a	-0.2	-0.3			1	-4
39	A	a	-0.2	0.1			1	-3
39	B	a	-0.3	0.0			-1	-3
40	A	b	-0.1	0.0			-5	-3
40	B	a	-0.2	-0.3			1	-3
41	A	a	-0.1	-0.1			2	-3
41	B	b	0.1	0.0			2	-4
42	A	a	-0.3	-0.1			1	-3
42	B	a	-0.2	0.0			2	-3
43	A	a1	-0.4	0.2			-1	-4
43	B	a1	-0.1	0.0			??	??
44	A	a	-0.1	-0.2			0	-5
44	B	a	-0.3	-0.2			2	-3
45	A	a	-0.2	-0.1			0	-4
45	B	a	0.0	-0.2			1	-4
46	A	a	0.0	0.2			0	-5
46	B	a	0.1	0.2			0	-4
47	A	b	0.0	-0.1			-5	-5
47	B	a	-0.3	-0.1			3	-3
48	A	a	-0.2	0.1			0	-4
48	B	a	-0.3	0.1			2	-4
49	A	a	-0.1	-0.2			0	-5
49	B	a	-0.3	-0.2			1	-5
50	A	a	-0.2	-0.1			-1	-3
50	B	a	-0.4	-0.1			1	-3
51	A	a	-0.2	0.2			0	-4
51	B	a	0.1	0.1			1	-4
52	A	c	??	??	-0.5	-0.6	0	-3
52	B	c	??	??	-0.4	-1.2	-1	-3

?? The values with this mark seem lost and we do not further try to find.

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