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The Compact Muon Solenoid Experiment

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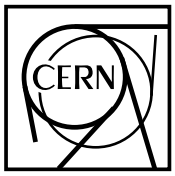

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Cutting of two marble dummy crystals in industrial prototype conditions

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Abstract

Two marble samples were cut to specified conditions with the tooling set designed for the mass processing of the 110’000 PbWO4 crystals of the CMS Electromagnetic Calorimeter. We wanted to test in particular the reproducibility of the electrical contact on the reference sphere, the accuracy of the new positioning tools at each cutting operation in their respective positions

1. INTRODUCTION

Two marble pieces were cut to specified conditions (1) with the tooling set No III (2). We wanted to test in particular the reproducibility of the electrical contact on the reference sphere, the accuracy of the new positioning tools at each cutting operation and of their respective positions.

The disk used in the test was supplied by Triefus with reference 1L1R 200T2X10 D3C76R50M5 of 25 07 1996.

The cutting disk flatness error might influence the geometry. The flatness error is given in the table below, I) new disk mounted on the spindle before cutting, II) disk mounted on the spindle after cutting, III) metrology of disk removed after cutting.

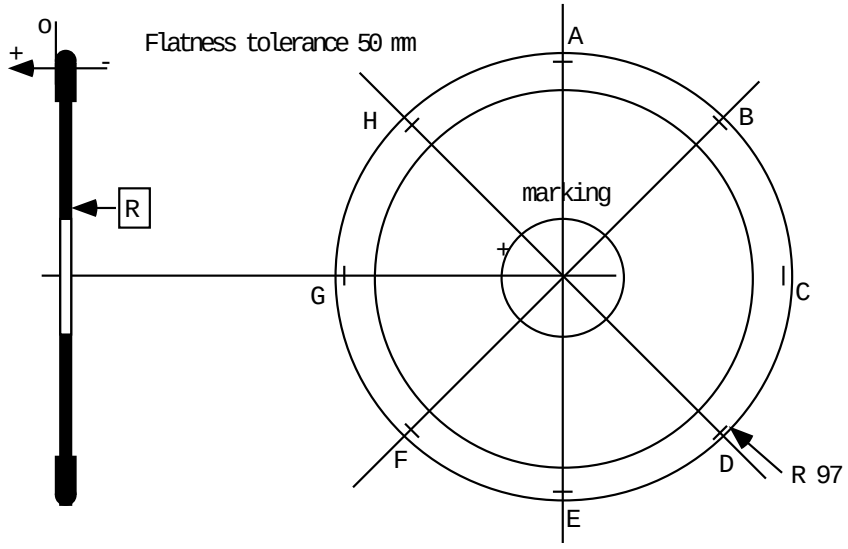

Fig. 1. Cutting disk flatness

Pos	A	B	C	D	E	F	G	H
I	-0,07	0	-0,02	0	-0,05	-0,04	-0,04	-0,02
II	-0,05	0	-0,02	-0,02	-0,01	-0,02	-0,06	-0,04
III	0	-0,028	-0,050	-0,052	-0,045	0	-0,074	-0,067

The cutting conditions are such that all six faces are produced by the same side of the cutting - the marked one - on the operator's side.

2. RAW MATERIAL DIMENSIONS

The raw marble bars are parallelepipeds of dimensions 35 x 35 x 240 mm^3.

3. DUMMY CRYSTAL FINISHED DIMENSIONS

The dummy crystal is to the same dimensions as real crystals for the beam test matrix: a right pyramid frustrum of height 230 mm with square bases 23,8 x 23,8 mm^2 and 20,5 x 20,5 mm^2, respectively

For real crystals, a lapping operation would follow the cutting and remove 50 μm per face; the dimensions for cutting are therefore:

height 230,1 mm = H

large base 23,9 x 23,9 mm^2= AR x AR

small base 20,6 x 20,6 mm^2= AF x AF

In mass production these dimensions are aimed at with a tolerance of:

+0; -100 μm

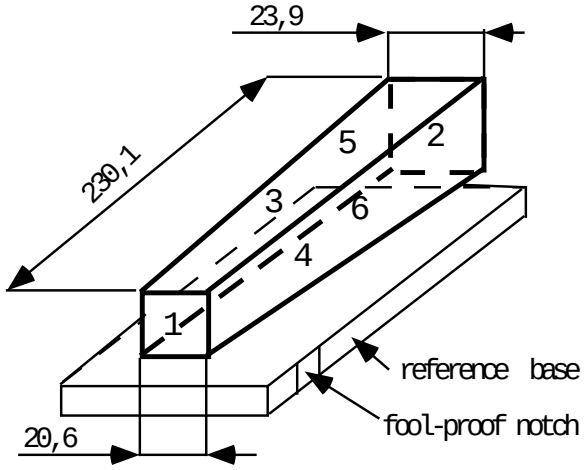

Fig.3. Standard dimensions and face numbering conventions

4. METROLOGY RESULTS

The metrology surveys of the cutting disks and of the finished samples were performed by R. Angelloz-Nicoud, MT-MQ. For the samples, the 'rapport de contrôle' dated 09 Dec. 1996 provides the following data:

4.1. FLATNESS OF EACH FACE IN μM

	face 1	face 2	face 3	face 4	face 5	face 6
Sample 1	1,2	1,2	5,7	2,3	7,5	7,5
Sample 2	1,9	1,6	13,1	4,9	8,8	10,7

4.2. PERPENDICULARITY OF END FACE EDGES (ANGLE IN °)

		face 3/5	face 5/4	face4/6	face6/3	total 360
Sample 1	Small end	89,9608	89,9602	90,1350	89,9440	0
	Large end	89,9596	89,9602	90,1350	89,9453	0,0001
Sample 2	Small end	89,8802	90,0306	90,0882	90,0009	-0,0001
	Large end	89,8788	90,0307	90,0883	90,0022	0

4.3. PERPENDICULARITY OF SIDE FACES (ANGLE IN °)

	face 3/5	face 5/4	face4/6	face6/3	total -360
Sample1	89,9635	89,9630	90,1379	89,9474	0,0118
Sample 2	89,8828	90,0333	90,0909	90,0048	0,0118

N.B. The total of 360,0118° is the sum of the side face angles of the pyramid.

4.4. DIMENSIONS OF CROSS SECTIONS AT END FACES IN MM

	small end	nominal	20,600		large end	nominal	23,900	
	face 3/4		face5/6		face 3/4		face5/6	
	side 5	side 6	side 3	side 4	side 5	side 6	side 3	side 4
Sample 1	20,654	20,626	20,572	20,537	23,942	23,908	23,907	23,867
S1-N	0,054	0,026	-0,028	-0,063	0,042	0,008	0,007	-0,033
Sample 2	20,629	20,597	20,603	20,561	23,907	23,869	23,942	23,893
S2-N	0,029	-0,003	0,003	-0,039	0,007	-0,031	0,042	-0,007

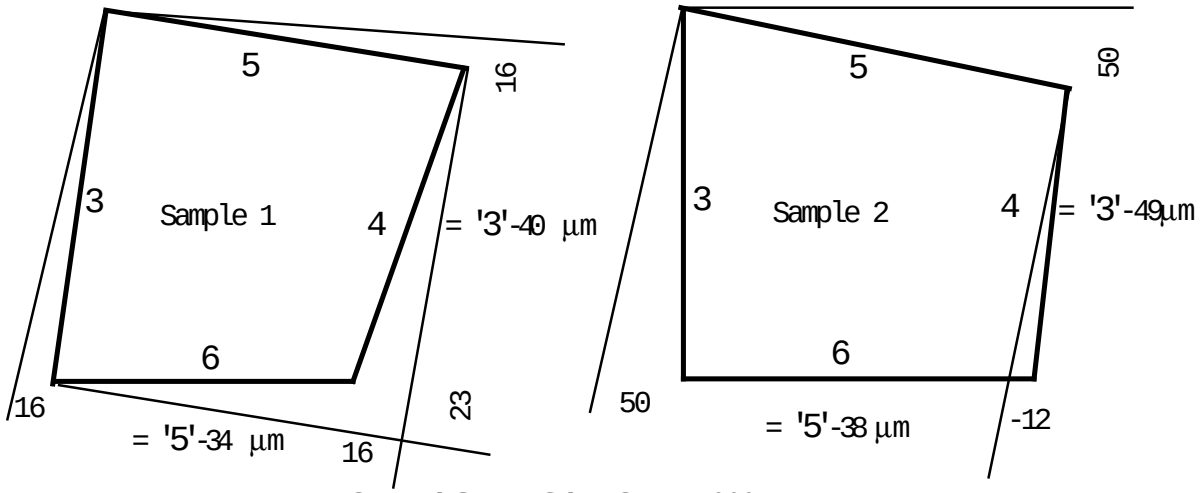

Fig.4.4. Off-squareness of sample transverse sections (end-face 2).
Dimensions (in mm) are consistent with side faces angular measurements.

5. ZERO SETTING ACCURACY AND REPEATABILITY

The zero setting procedure consists in putting the cutting disk (at its larger off-plane point) in contact with a precision reference sphere. The sphere is secured on a high precision mount identical to the crystal reference base. The sphere position to the tooling corresponds to the crystal nominal position with a precision of 20 μm. The contact is confirmed by an electrical device. The disk is then displaced by a computed amount corresponding to the crystal nominal face position. As the same sphere reference mount will calibrate every tool in sequence, the error at the zero setting results on the sphere diameter accuracy, on the proper selection of the disk contact area, on the repeatability of the electrical contact and on the precision of contact between the sphere reference base and the tooling stops. An improved disk flatness reduces the uncertainty on the place where it touches the sphere.

We compare the expected nominal value and the measured value of the cross section of face 2 near the disk contact to the reference sphere. The cutting of the two faces producing one measured dimension results on two zero settings with a global precision of + - 40 μm.

Nominal	23,900	S1-N	S2-N
face 3/4	side 6	0,008	-0,031
face5/6	side 3	0,007	0,042

6. SINE RULER ACCURACY

The sine ruler accuracy is verified by comparing for two samples produced with the same setting the difference between corresponding cross section measurements at the two sample ends, and the nominal value. The shimming is performed on a 300 mm sine ruler for the half angle of each face, i. e. (3,300 / 2 * 230) * 300 = 2,152 rounded to 2,15 mm

For face 3 vs. face 4, the same face of the magnetic table touches identical but inverted piles of shims. As there is a set of tooling stops for each face, their respective parallelism might contribute to the same angular error for both samples.

For face 5 vs. face 6, opposite faces of the magnetic table touch identical but inverted piles of shims. The same set of tooling stop is used for both faces. This explains why the difference between the two samples is small. In this case the possible angular error would come from the error in parallelism of the magnetic table opposite faces.

The contact between the magnetic table, the shims and the sine ruler touches (detailed description of tooling in ref. 2) was carefully checked - a 1 mm shim was added to each touch - and the difference from nominal (L-S) may be explained by an elastic deformation of the sine ruler itself, to be checked.

Conversely, the accuracy with which this set value is kept for the two samples is demonstrated by the last line of the table.

Cross section		face 3/4		face5/6	
	Nominal	side 5	side 6	side 3	side 4
Sample 1 L	23,900	23,942	23,908	23,907	23,867
Sample 1 S	20,600	20,654	20,626	20,572	20,537
1 (L - S)	3,300	3,288	3,282	3,335	3,330
Sample 2 L	23,900	23,907	23,869	23,942	23,893
Sample 2 S	20,600	20,629	20,597	20,603	20,561
2 (L - S)	3,300	3,278	3,272	3,339	3,332
1-2 (L-S)	0	0,010	0,010	-0,004	-0,001

7. CONCLUSIONS

We see that by re-setting after a first cutting operation, we could produce samples to the required tolerance of +0 ; -100 μm. However, to safely achieve this condition in mass production, we have to improve the reproduceability of the zero setting to reduce the absolute setting error, mainly by checking the sine ruler stability, and to improve the reproduceability of the contact of the reference bases to the tooling stops. Finally, tests on real $PbWO_4$ crystals are required on a sufficient sample number to validate the method and the tooling.

11. REFERENCES

[1] **CMA Int. Note**. M. Lebeau. Setting for the cutting of a $PbWO_4$ crystal boule to standard dimensions for beam test matrix with tooling version III. 30 04 1996.

[2] **CMS Note 1997/024**. M. Lebeau. Principles of the cutting method proposed for the $PbWO_4$ crystals of the CMS electromagnetic calorimeter. 01 04 1997.

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