FABRICATION OF A QUADRANT-TYPE ACCELERATOR STRUCTURE FOR CLIC

T. Higo*, Y. Higashi, H. Kawamata, T. Takatomi, K. Ueno, Y. Watanabe and K. Yokoyama,
KEK, Tsukuba, Ibaraki 305-0801, Japan
A. Grudiev, G. Riddone, M. Taborelli, W. Wuensch and R. Zennaro,
CERN, Geneva, Switzerland

Abstract

A study was done on the fabrication of the quadrant for the X-band accelerator structure of CLIC. By using a ready-made multi-axis milling machine and carbide tools, we typically reached an error level of 5 microns. The typical local profile shape was controlled within a tolerance, ± a few microns, but the absolute positioning of the shape should still be improved by several micron level to address the four rod fabrication for a structure.

BACKGROUND OF THE STUDY

KEK has long been developing the X-band high gradient accelerator technology for the electron-positron linear collider, NLC/GLC[1]. After the recommendation of cold technology in 2004 by the international technology recommendation panel[2], ITRP, the X-band activity at KEK has focused on some basic studies[3].

In the end of 2006, the CLIC[4] re-optimized its design and reached the choice of the frequency from 30 GHz to 12 GHz and the gradient of 150 MV/m to 100 MV/m[5]. This choice is very close to the design of the X-band technology KEK has been working on. Therefore, X-band group of KEK decided to collaborate with CERN on the CLIC acceleration technology.

One of the special CLIC accelerator designs is the choice of the quadrant as a constituent of the accelerator structures. This choice makes various pros and cons; considering these, we decided to address the quadrant fabrication study as one of our basic research activities. Some of the studies were presented by T. Takatomi[6]. An excellent result was also presented by R. Zoetewey[7], though we proceeded independently and no feedback from the discussion.

STRATEGY OF THE STUDY

Since the fabrication of a quadrant was new to KEK, we set three stages. As the first stage, short (~10 cm) models with three cells in the middle were made by five different vendors. Taking the experience of this stage into account but basically succeeding the same machine and same tool, a full quadrant was made as the second stage. From these study, we estimate the feasibility of the structure fabrication as the last stage.

In the present paper are mainly described the study results of the second stage.

RESULT OBTAINED IN SHORT MODELS

The 3D shape was formed by taking the 3D CAD file in stp format. This file was modified by KEK with taking the last three cells.

Result of the study

A picture shown in Figure 1 is one of the products. Detailed technical information can be seen in a technical note[8]. The surface roughness made by a carbide tool gave us the worse result than that specified in the drawing, Ra~0.1μm. This result was estimated from the beginning but we have not tried the diamond tool this time since we did not have enough information on a diamond tool performance. On the other hand, we confirmed that the local profile of the cell could be reproduced within a few microns.

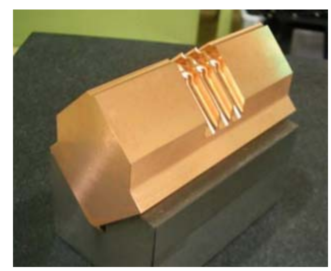


Figure 1: One of five short-cut models.

FABRICATION OF FULL MODEL

Reviewing the result of the above short model study, we decided to make a full quadrant based on the same technology but with more care on the dimensions of the longer object. The 3D drawing was retrieved from CERN EDMS with the name CLIAAS110049. The actual production study was done by two vendors, Hitachi Ltd.[9] and U-corporation[10].

Some Machining Conditions

The material for the present fabrication was set as C150, which contains 0.15% Zr in usual OFC copper. The material was supplied by Hitachi Cable Ltd. as rods with the diameter of 65mm. We prohibited the annealing of the material because of the expected deterioration of precipitated Zr performance.

The precision milling machines were used. Two machines made by YASDA were used, YBM-800N, a three-axis with additional rotation capability, and H30i, a full 5-axis machine. The nominal reproducibility of the positioning is 1 micron level. The machines are located in an air-conditioned area. The oil running through the

* toshiyasu.higo@kek.jp

machine is also exposed on the work to be machined. The spindle rotation speed was set at 5000~8000 rpm range.

The carbide tool with radius of 2mm was used. The shape tolerance of the tool was assured by the vendor as typically ±2~3 microns. This error is marginal for the ±2.5 micron shape tolerance but this was the best we could acquire commercially.

Naturally t machining was performed in several stages. The outer reference planes are the basic reference for realizing the severe precision. Therefore, such surfaces were machined after rough machining of big volume. The final machining thickness ranges from 100 microns to 5 microns, depending on the preference of the vendors reflecting various machining conditions.

Products

One of the machined products is shown in Figure 2. KEK made a thorough evaluation in addition to the vendors.

Figure 2: A full quadrant sitting on CMM.

RESULT OF FULL MODEL STUDY

The overall agreement in the measurements by KEK and by vendors was within several microns. In the present paper, we refer to those measured by KEK. The agreement between KEK and vendor should be a micron level in order to make a feedback during the production period.

At KEK, the dimensions were measured by a 3D coordinate measurement machine (CMM), UPMC-850 CARAT made by ZEISS. The profiles were also measured with the same machine. The surface roughness and detailed local shapes were measured by a profile measurement machine, Formtracer CS-5000 of Mitsutoyo Corporation. It used a touch probe of typically five-micron sapphire.

Reference Planes

The flatness of one of the reference planes is shown in Figure 3. The points with four colours represent the measurements along the lines separated from the beam axis by 10, 15, 25 and 45mm.

It was found that the central area where the cells are located was within 2~3 microns. However, large deviation appears approaching to the end, where a large channels for the wave guide are located. This effect should be eliminated for the good assembly to make a structure out of four rods. The reference plane flatness should be improved by a factor 2~3 for the stable control of the cell dimensions.

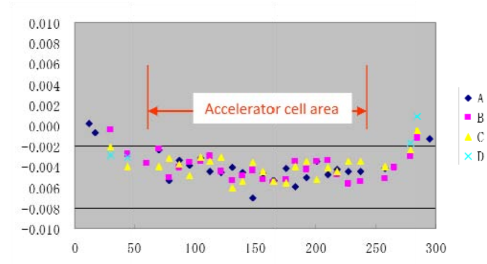


Figure 3: Flatness of the reference plane.

Longitudinal Position Along Beam Axis

The cell positioning along the beam axis is important to make a symmetric cell when assembled to form a structure. In Figure 4 is shown a typical example. It shows a slow drifting component in addition to several micron level errors. Both of these errors should be reduced.

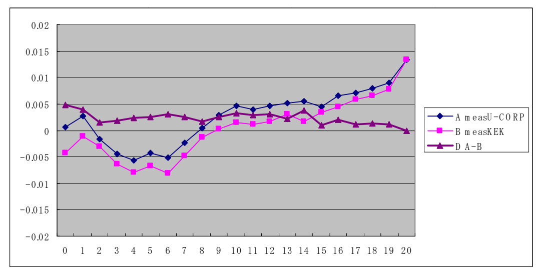


Figure 4: Distance from the end of the full quadrant.

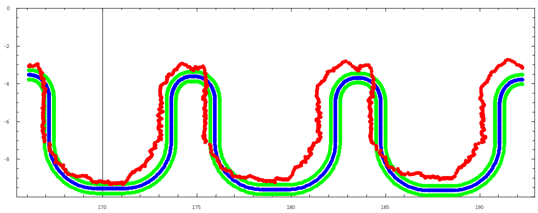
Cell Profile

The profile measurement was performed by CMM with a KUM program. The profiles were scanned with a probe with 0.2N. The results are shown in **Figure 5**. The blue curve indicates the design profile, while green ones the tolerance band of ±2.5 microns. The red curve is the actual measurement. The actual measurement and the tolerance band are plotted with a magnification of 100.

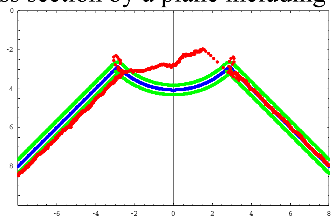
As shown in (a), there appeared several micron error in beam axis direction. This error should be carefully eliminated by taking into account such problems as temperature drift and positioning between a long distance. Tangential discontinuity at the center of each beam aperture, where the cutting was separated into different stages, was observed. It should be improved.

Surface Roughness

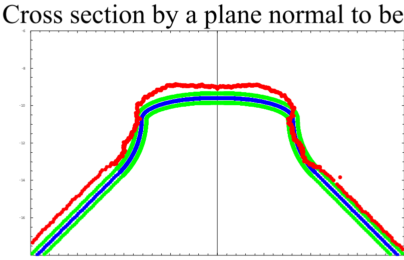
Surface roughness was measured using a stylus of 5 microns with Formtracer. Since the tool pass is parallel or perpendicular to the beam axis, we measured the roughness along the line parallel and normal to the beam axis as shown in Figure 6 (a). This typical example shows a roughness Ra of 0.2 μm and 0.4 μm for the #7a and #7b. The cut off wavelength of this case was set to 0.8mm reflecting to the JIS standard. However, thinking from the RF field point of view, the slow variation of the surface



(a) Cross section by a plane including beam axis.



(b) Cross section by a plane normal to beam axis.



(a) Cross sections by a plane normal to beam axis.

Figure 5: Typical profiles.

shape does not play an important role. Then we analysed with the cut off of 0.2mm, resulting in the roughness value of 0.2μm. With this condition, the roughness values were ranging from 0.1μm best to 0.4μm at worst. It is noted that the roughness along the tool passage was better than that perpendicular to the passage.

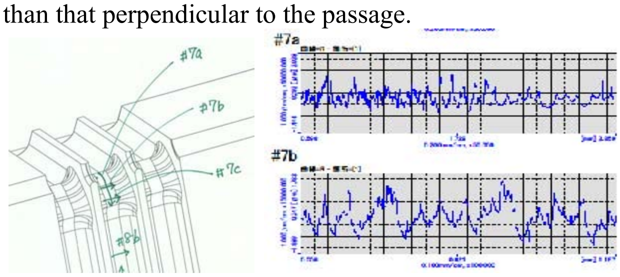


Figure 6: Typical roughness measurement result.

Rounding of Edges

We adopted intuitively a radius of 50 microns in the present case to taste the feasibility of rounding the edges.

In Figure 7 is shown a typical example at beam aperture. The left edge was magnified and shown in the right. This rounding was not very reliable in our case and it should be improved by a few 10 micron level.

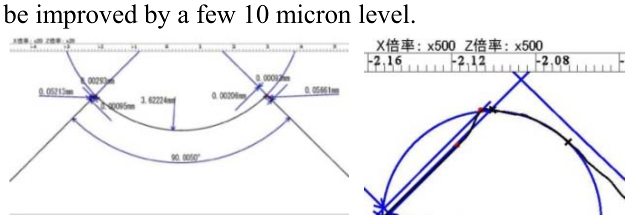


Figure 7: Rounding of the edge specified as 50 microns.

SUMMARY AND CONCLUSION

The fabrication of a full quadrant can be performed with the present ready-made machine using carbide tool. It seems better to use 5-axis machine to get rid of the cutting at chizel point. We admit that the improvement is needed for structure fabrication in the positioning accuracy and the reference planes, both by several micron level, the surface quality, the edge rounding, etc.

ACKNOWLEDGEMENTS

This work is supported by an collaboration between CLIC group, CERN and X-band group, KEK. The authors greatly thank the director generals of both laboratories for encouraging the program. We specially acknowledge Drs. J.-P. Delahaye and Y. Kamiya of the accelerator divisions of both laboratories for supporting the program.

REFERENCES

[1] International Study Group Progress Report, KEK Report 2000-07, SLAC R-559, April 2000.

[2] ITRP, International Technology Recommendation Panel, presented in Beijing, China, 2004, http://www.interactions.org/cms/?pid=1014290.

[3] T. Higo et al., "Normal Conducting High-Gradient Studies at KEK", THP038, LINAC06, Knoxville, Tennessee, USA, 2006.

[4] I. Wilson, "The Compact Linear Collider CLIC", CLIC NOTE 617, CERN-AB-2004-100, Geneva, 2004.

[5] H. H. Braun, "Towards a Multi TeV Linear Collider; Drive Beam Generation with CTF3", APAC07, Indore, India, 2007.

[6] T. Takatomi, "Quadrant fabrication study", 2nd collaboration meeting on accelerator structure design and test program, KEK, May, 2008, http://indico.cern.ch/conferenceDisplay.py?confId=30911.

[7] R. Zoetewey, "Manufacturing experience with acceleration structures", ibid.

[8] T. Higo et al., "Test cut studies for the fabrication of the CLIC damped structure, TD18_VG2.4_Quad", Nextef-Technical-Note 2008-01, http://www-linac2.kek.jp/nextef/.

[9] T. Watanuki et al., "Trial fabrication of CLIC quadrant-type accelerating structure", in Japanese, Proc. of Mecha-workshop, KEK, April 2008, Japan, http://www-mec.kek.jp/kousaku/open/report/MechWork/2008/.

[10] S. Hirai, "The machining of CLIC quadrant test structure", in Japanese, ibid.