THE ALIGNMENT OF COMET

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The COMET cyclotron was adjusted by the PSI alignment group in March 2004. The pre-alignment of the supporting structures was carried out in December 2003 by using a dummy ring. Additional pressure tests were performed to verify the stability of the vertical bearings.

INTRODUCTION

The COMET cyclotron (Compact Medical Therapy) has an approximate weight of 90 tons and is supported by 4 heavy-duty bearings mounted on 4 columns. The bearings also serve as adjustable feet but are only moveable in the horizontal plane; a vertical adjustment is not foreseen. The support structure of the cyclotron consists of four strutted steel columns. The pre-alignment with a dummy ring took place in December 2003 and the final alignment with the lower part of the cyclotron was completed in March 2004. Because of high demands of accuracy in a range between 0.1 mm to 0.2 mm, the alignment procedure has been performed using a high precision instrument, the Lasertracker LTD500 (Leica).

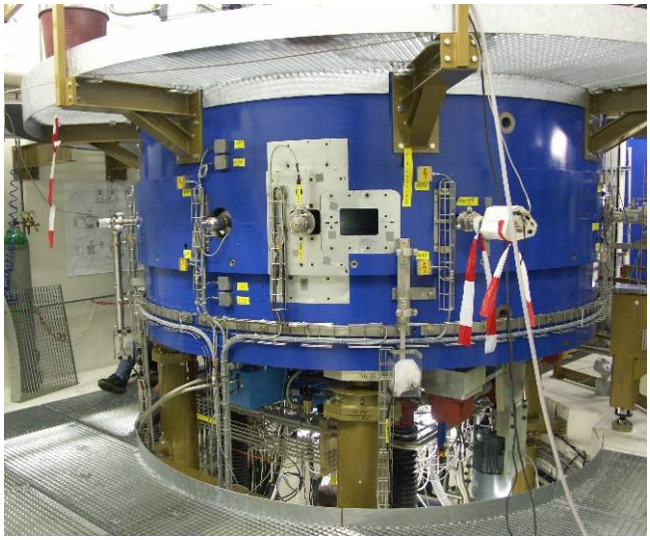

Fig. 1: Cyclotron COMET with its support structure.

PRE-ALIGNMENT

Due to the fact that a device for the vertical adjustment of the Cyclotron is not foreseen, the heavy-duty bearings had to be pre-adjusted with individually manufactured customised shims. To compensate the deformation in height by weight, a statically determined offset of 0.5 mm was added to their dimensions.

The pre-alignment was realised in December 2003 using a dummy ring made of stainless steel. The task included the determination of height differences and control measurements of the mounting holes. The dimensions of the dummy ring are 3275 mm in diameter and 50 mm in thickness. The position of 16 reference holes (Fig. 3) drilled on the outside surface are identical with their position on the lower part of the cyclotron (yoke ring) after allowing for the required 0.5 mm deformation offset. A further pair of reference points indicates the theoretical extracted beam direction inside the accelerator.

PRESSURE TESTS

The stability of each individual bearing has been verified by a pressure test. A force of 40 tons was applied to the bearings with a hydraulic press. Any resulting differences were measured with dial gauges. The results show that no changes in the dimensions occur.

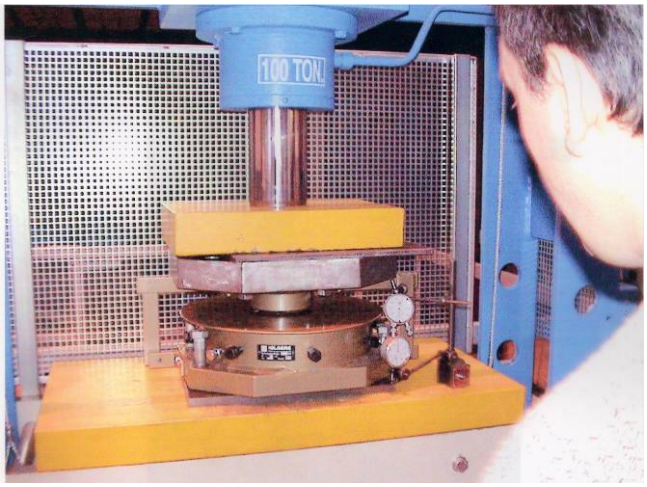

Fig. 2: Setup for the pressure tests.

VERTICAL ALIGNMENT

In Fig. 4, one can see the vertical differences of the reference points in a radial unwind display together with the directly measured top of the columns. The diagram clearly shows that the bearing at the North-West-side is too low (approx. 2.5 mm), which causes a sagging of the dummy ring. In general, each bearing is roughly 0.5 mm too low compared with its nominal position. To compensate these errors in height, all bearings were fitted with a customised shim.

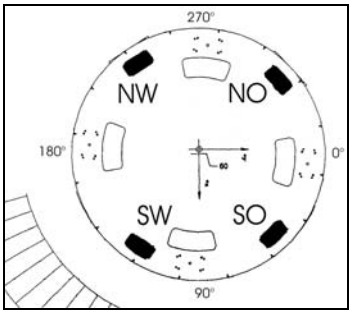

Fig. 3: Overview columns.

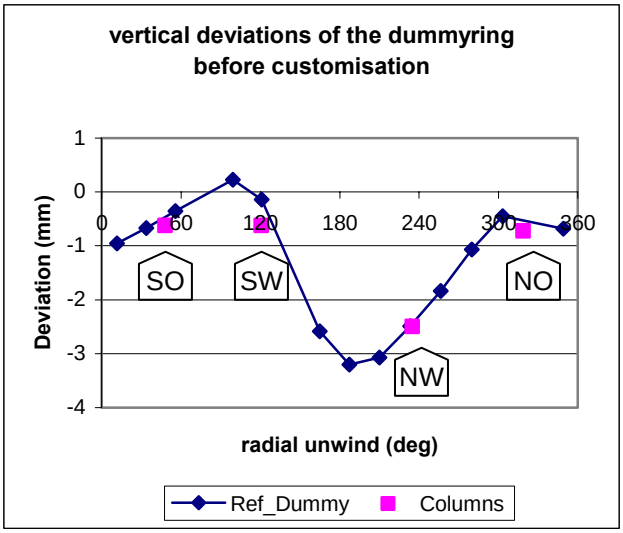

Fig. 4: Deviation before customisation of the shims (radial unwind display).

Fig. 5 shows the vertical deviation after installation of the customised shims. The big difference at column North-West is eliminated. The notable sagging of the dummyring is due to the larger gap between the North-West and South-West columns. However, the yoke ring of the cyclotron is much more stable and this effect should disappear. The nominal height of the bearings is achieved.

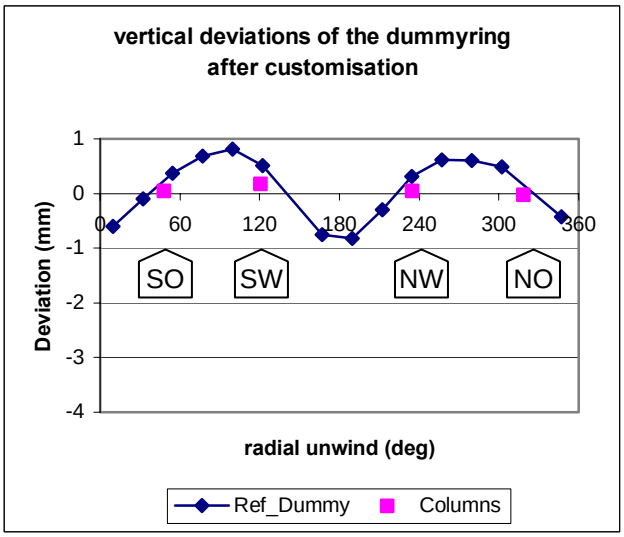

Fig. 5: Vertical deviation after customisation of the shims.

HORIZONTAL ALIGNMENT

For alignment in the horizontal plane, adjusting screws at the bearings were used. The dummy ring could be moved to its nominal position, which results in the yoke ring of the cyclotron also being moved to its design position. This pre-alignment guaranteed that we will not reach any limits with the bearing adjustment screws and a final alignment of the cyclotron will be possible.

FINAL ALIGNMENT

After the installation of the lower yoke ring of the cyclotron in March 2004, the surveying group aligned the COMET to its final theoretical position. The mechanical tolerances of the reference points is given as ±0.1 mm. Table 1 shows the nominal/actual comparison for the 16 reference points and the mean value in all three dimensions.

Nominal / actual comparison			
PID	**ΔX[mm]**	**ΔY[mm]**	**Height ΔZ[mm]**
Zyk_1	0.11	0.03	0.04
Zyk_2	0.14	0.06	0.07
Zyk_3	0.15	0.02	0.08
Zyk_4	0.17	-0.03	0.11
Zyk_5	0.13	-0.06	0.10
Zyk_6	0.00	-0.03	0.05
Zyk_7	0.04	-0.09	0.03
Zyk_8	0.07	-0.03	-0.06
Zyk_9	0.01	-0.03	-0.06
Zyk_10	0.05	0.04	0.07
Zyk_11	0.11	0.06	0.05
Zyk_12	-0.01	-0.01	0.07
Zyk_13	-0.07	0.06	0.05
Zyk_14	-0.07	0.12	0.07
Zyk_16	0.05	0.10	0.07
Average	**0.06**	**0.01**	**0.05**

Table 1: Nominal/actual comparison of radial reference points at the cyclotron.

CONCLUSIONS

As can be seen in Table 1, the differences between the nominal and actual values in height are within 0.11 mm. That means that the statically determined offset and the pre-alignment arrangements were correct. The maximum range in the horizontal position is below 0.17 mm. Further alignment is not necessary and not meaningful, since we are working very close to the accuracy limit of the instrumental set up, which is in the range of 0.05 mm. The required accuracy for the alignment of the cyclotron is clearly excelled.