APPLICATION OF PRECISION MECHANICAL ENGINEERING TECHNIQUES TO THE DESIGN OF A MODERATE ENERGY BEAM TRANSPORT FOR THE FAA EXPLOSIVE DETECTION SYSTEM*

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Abstract

This paper discusses the application of precision mounting and alignment techniques to a moderate energy beam transport system (MEBT) used on the exit of a 1.75 MeV RFQ. While frequently found in optical systems, techniques such as kinematic mounting, and degree-of-freedom decoupling, are not as widely used for accelerator components. The MEBT consists of one permanent magnet quadrupole, four electro magnet quadrupoles, and one debuncher cavity. Included in the paper are discussions of design and fabrication considerations as well as, installation, alignment and operations experience during the successful implementation on a working accelerator.

I. INTRODUCTION

Los Alamos Group N-2 (Advanced Nuclear Technology) has undertaken a project to prototype an accelerator-based system for explosive detection using the nuclear resonance absorption technique. We were asked to provide the mechanical design for a beam transport starting at the end of the 1.75-MeV radio frequency quadrupole (RFQ) to the target location, some 166 cm downstream. The physics design of this moderate energy beam transport (MEBT) called for one rare earth permanent magnet quadrupole (PMQ) at the exit of the RFQ, followed by two electro-magnet quadrupoles (EMQ's), a debuncher cavity, and finally two more EMQ's.

Our goal was to provide a robust mechanical design that would at the same time employ some of the precision alignment techniques found in optical systems for the positioning of the MEBT components in five of the six degrees-of-freedom.

In order to minimize alignment time we attempted wherever possible, to decouple the degrees-of-freedom, thereby eliminating the time consuming "cross talk" between the axes.

II. DESIGN

The PMQ used for focusing the beam was mounted directly onto the downstream vacuum cover of the RFQ.

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The four EMQ's and the debuncher cavity were mounted on an adjustable support stand. The support stand consists of a 1.25 inch thick aluminum plate bolted to a structural steel frame adjustable in X, Y, and Z. The MEBT components were aligned to the theoretical beam line within a diametrical tolerance of .002 inch and they were aligned azimuthally to the RFQ within 1.0°. A target assembly, provided by the experimenter, was attached to the downstream end of the accelerator. Figure 1 shows a schematic of the accelerator with the target assembly attached.

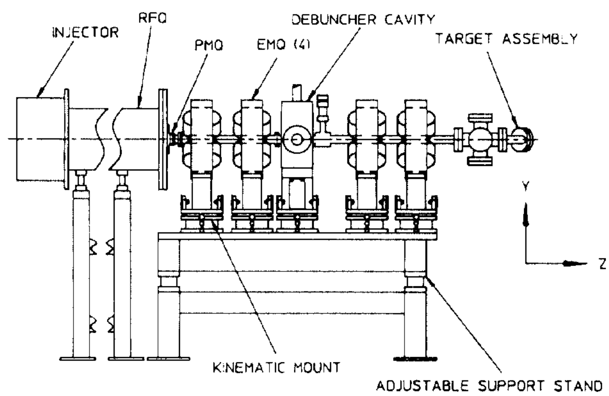

Fig. 1. Schematic of Accelerator.

Several mechanical techniques were used to fulfill the alignment requirements of the accelerator components. The PMQ was held in the center of its holder with a Tolerance Ring.+ The azimuthal position of the PMQ was fixed by pinning it to the holder using a standard .060 inch diameter dowel pin. Another pair of standard .125 inch diameter dowel pins were used to orient the PMQ and holder assembly to the RFQ end flange.

The EMQ's were attached to kinematic mounts that were designed to allow for adjustment in the Y direction. The kinematic mounts used hardened steel elements for a cone, vee groove, and flat that mated with commercially available hardened steel tooling balls. The relative position in Y of the tooling balls with respect to the magnetic center of the EMQ was adjustable. The tooling balls were each

+A product of USA Tolerance Rings, West Trenton, New Jersey.

attached to the end of a 5/8-24 threaded shaft which was preloaded against a base plate. A dial indicator of .001 inch graduations was mounted near each of the threaded shafts. The dial indicators measured the relative vertical displacement of the EMQ. By rotating the three threaded shafts until each dial showed the same amount of movement, true vertical motion was ensured. By using this system, it was possible to resolve the vertical motion of the EMQ to a resolution of less than .001 inch.

To accomplish roll adjustment, each EMQ was mounted in a vee block and the EMQ was rotated with a lever arm attached to the magnet ring. Hardened steel wearing surfaces were attached to both the EMQ and to the vee block to minimize wear and to ensure precise rotation. Rotation was actuated by turning a commercially available threaded ball foot against one side of the lever arm. To eliminate lash, the lever arm was preloaded against the ball with a commercially available spring plunger.

To provide adjustment in the X direction, the assembly was mounted on a commercially available dovetail slide whose axis of travel is perpendicular to the beam direction. Figure 2 shows the EMQ and its mounting system.

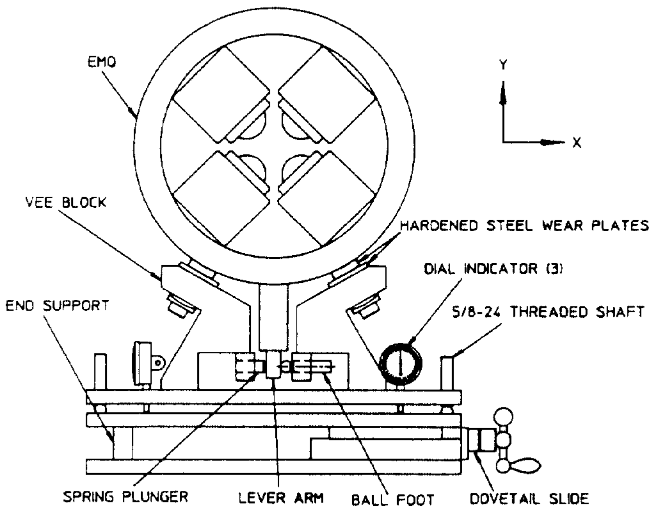

Fig. 2. EMQ and Mounting System.

The debuncher cavity was also mounted on a system similar to that of the EMQ's. Provisions for roll adjustment to the debuncher cavity were not necessary.

III. FABRICATION

After final magnetic mapping of the permanent magnet quadrupole, a .0643-.0663 groove was machined into its outer aluminum jacket. The groove position was 45° from the north pole of the magnet. Subsequently, the fit and position of the mating dowel pin in the holder were carefully specified, as were the mating conditions of the outer dowel pins for assembly with the end flange of the RFQ. As a result, fabrication of the PMQ holder was simplified, and the need for active alignment of the PMQ was eliminated. Figure 3 shows the tolerance specifications assigned to the PMQ holder.

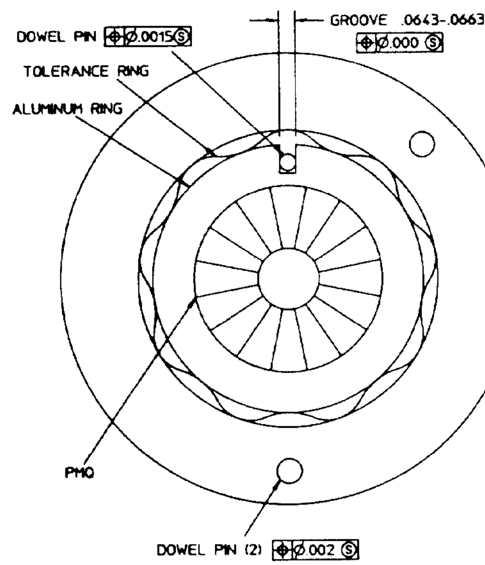

Fig. 3. PMQ and Holder Assembly.

Our previous experience in the design of kinematic systems revealed that cones and vee grooves for kinematic mounting devices having the proper geometry and hardness are not commercially available. Typically, they need to be custom fabricated for each application. However, for the EMQ's and debuncher cavity we determined, that by using other readily available, inexpensive, hardened steel elements, the same kinematic effect could be accomplished for substantially less cost. A cone effect was accomplished by using a steel drill bushing of hardness RC 62-64 and .500 inside diameter mated with a .625 diameter tooling ball. A vee groove effect was accomplished by mounting two standard .500 diameter steel dowel pins of hardness RC 36-42, with their axes parallel to each other and perpendicular to the axis of the 5/8-24 threaded shaft. The flat used in the kinematic mount was a commercially available steel rest button of hardness RC 40-45. Figure 4 shows the three elements of the kinematic mount used for the EMQ's and the debuncher cavity.

The two wear plates on the magnet ring of each EMQ were made from A2 tool steel. They were premachined, hardened, then attached to the EMQ. They were then final ground concentric with a precision alignment pin that was sized to the four inside pole tips of each EMQ. Doing this ensured precise rotation of the EMQ about its magnetic center. ++

++This mechanical determination of the magnetic axis was used because some of the existing fiducials locating the magnetic axis had been damaged or removed.

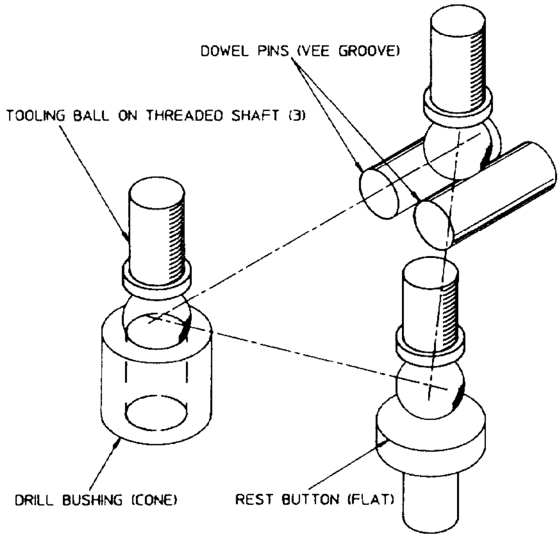

Fig. 4. Elements of Kinematic Mount.

Figure 5 shows the machining technique used for machining the EMQ wear plates.

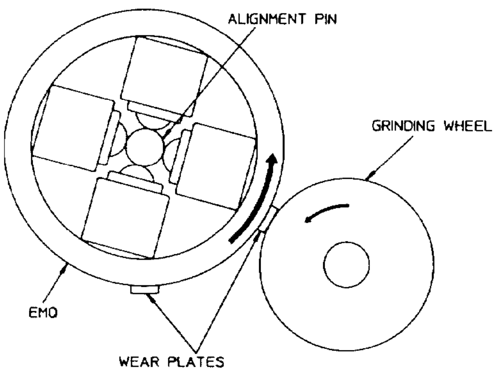

Fig. 5. Grinding EMQ Wear Plates.

IV. INSTALLATION, ALIGNMENT AND OPERATION

The next step was to install and align the MEBT components on the beamline. A line of sight through the RFQ was established using a Brunson model 160 line scope sighting through the center of the injector and a backlit pin hole in the exit end of the RFQ. The four EMQ's, the debuncher cavity and their mounts were assembled and pinned to the top plate of the support stand. Initially, EMQ's 1 and 4 were positioned on their mounts so that all adjustments were in mid-range. A precision fit pin having a back-lit pin hole through its axis was inserted into the centers of EMQ's 1 and 4. The line established by the pin holes at EMQ's 1 and 4 was made colinear with the line scope using the support stand adjustments. The remaining two EMQ's and the debuncher cavity were brought into position by using the X and Y adjustments while sighting on back lit pin holes such as those used on EMQ's 1 and 4. The PMQ and holder assembly was attached to the down stream end flange of the RFQ. A final operation to check the repeatability of the kinematic mounts was then performed by lifting each EMQ and the debuncher cavity completely off their kinematic mounts then replacing them. No measurable X and Y displacement of these elements was observed. The angular alignments of the EMQ's was determined by the experimenters during assembly of the beam tube. A quartz window was installed on the end of selected segments of the beam tube and each EMQ was adjusted until the desired visual beam spot was obtained. The target assembly was installed on the downstream end of the beam tube to complete the assembly. Figure 6 shows the completed accelerator.

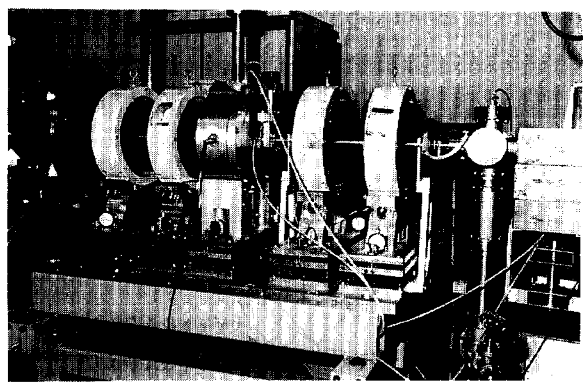

Fig. 6. Assembled Beam Transport System.

V. CONCLUSION

The accelerator was commissioned and experimental data has been obtained. During initial installation of the beam tube and diagnostics and during routine maintenance it has been necessary to remove and replace the PMQ, EMQ's and debuncher cavity by disassembling them at their kinematic mounts. Each time they have been replaced on the beam line with no measurable shift in their positions. When it is necessary to re-adjust some of the beam elements, each adjustment is made predictably and without concern for coupled motion effects. The application of precision mechanical engineering techniques to the design of this accelerator has proven to be effective.