DESIGN AND DEVELOPMENT OF COLLIMATOR FOR 9 MeV BARC-ECIL LINAC

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Abstract

High Energy electron beam technology is useful for both fundamental and applied research in the sciences, and also in many technical and industrial fields. It has been estimated that there are approximately 26,000 accelerators worldwide. The collimator is designed to function with a 9 MeV LINAC Test Facility (LTF) at ECIL, Hyderabad. The accelerated electron beam hits a tantalum target and X-Rays generated though the target are fed to the collimator. Thereafter, collimated high energy X-Rays will be used for cargo scanning.

The X-ray collimator will complement the existing system at LTF, ECIL to get collimated fan beam. A collaborative effort has been made to identify novel and advanced materials to achieve low coefficient of friction for various lateral and angular movements of collimator plates weighing nearly 5 tons. Complex numerical calculations simulating extreme conditions and experimental tests have been undertaken using Ansys. In parallel, an innovative modular design concept of the assembly has been developed to allow fitting in alternative materials, minimizing the load induced deformations, withstanding accidents and accepting desired radiation doses.

The collimator plates are made up of mild steel blocks of IS 2062A grade ensuring high geometrical stability. The assembly structures for the collimator are made up of high stiffness I-beams ISMB 150. Each plate has been machined with high precision Electric Discharge Machining (EDM) and Surface Grinding processes. The plates are also hard chrome plated to provide corrosion resistance and increase surface hardness. A full scale collimator prototype has been manufactured to validate each feature of the new design at the LTF, ECIL, Hyderabad.

INTRODUCTION

The collimator is supposed to help in achieving a collimated planar beam or “fan beam”. When the electron beam from the LINAC hits the target it generates X-Rays which are scattered in all directions but most of the X-Rays goes in forward direction of beam. These X-Rays are fed to a series of MS blocks which have continuous slits but of increasing width. The first block has a slit of width 4mm by 4mm. The last block gives out the X-Ray beam with same thickness of 4mm but of more length which has been increased as per a particular angle over the series of MS blocks collimating it. This beam is to be used for non destructive scanning of dense cargo. The walls opposite to collimator output slit have photo diodes which through appropriate interfaces generate an image of the scanned cargo and identify the objects in it with pre defined colour coding scheme. This could be a highly useful system to be used for scanning of all incoming cargo and prove as an aid for generating more revenue and avoid goods trafficking prevalent at our shores and also ensure better national security standards.

DESIGN

To get the fan beam of 4 mm width, beam is to be collimated. Total thickness of plate required is 900 mm. Due to practical difficulty in slit cutting of 4 mm width and 30 degree taper angle, this thickness is divided in 18 numbers of plates of 50 mm thickness. Total weight of plate assembly of size 900mmX800mmX800mm is 4527 kg. Plate assembly is supported by I beam structure shown in fig-1.

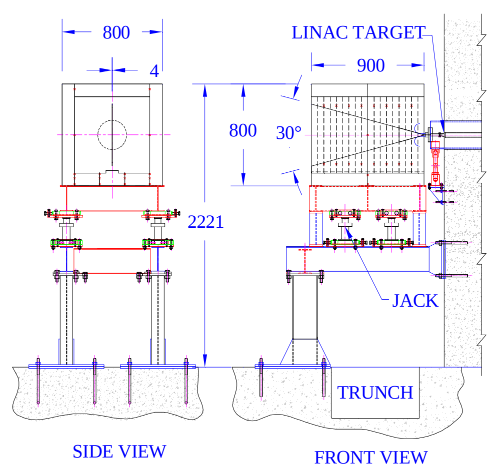

Figure 1: Collimator for 9 MeV ECIL-BARC LINAC

Our objective of the support structures design was to aim for the maximum deflection of horizontal I-beam due to weight should be less than 1 mm. The foundation bolts are selected based on the maximum load and moment coming from the structures.

Detailed analyses were carried out in ANSYS in two stages. In the first stage of analysis all the plates were modelled together of size 900mmX800mmX800mm. The base frame supports were provided in the vertically upward direction. The material elasticity, density are defined for steel. As load is only due to self weight the gravity is defined as 9.81 m/s^2 in the vertically downward direction. Case is solved for the deflection and reaction at the supporting edges. The deflection profile is shown in Figure-2. Maximum deflection in plate structure is 0.26 micron.

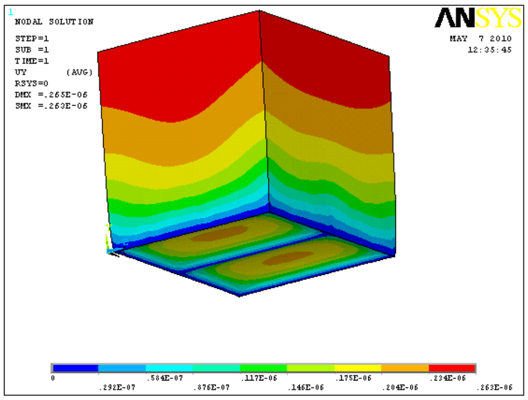

Figure 2: Deflection profile of plate assembly.

In the second stage of the analysis wire frame modelling was done. The reaction forces per unit length at the supporting edge of the plate from the first analysis were applied as the load in the second stage. All the supporting frame structures selected are I beam of ISMB 150. Beam element is selected and line meshing is done. Moment of inertia, section area are defined as per beam size.

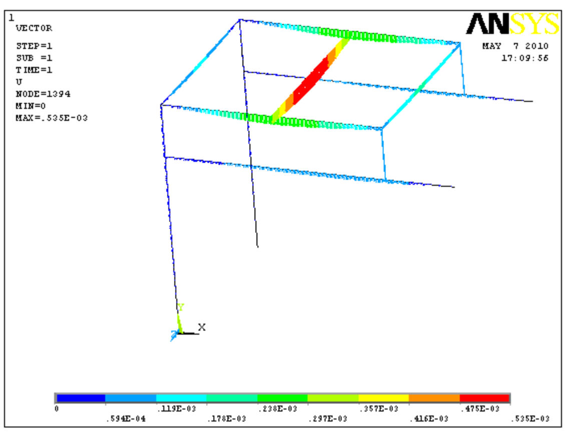

Figure 3: Deflection profile of I-beam structure.

The supporting points from wall and ground are fixed. The case is solved in ANSYS. The deflection profile obtained is shown in figure-3. The maximum deflection is coming at the centre of the middle supporting horizontal beam of 0.53 mm which is well with in 1mm limit.

The reaction forces and moments at the fixed points to the wall are also extracted for the selection of foundation bolt size. At the wall side load and moment at both locations are 9962N and 1470 Nm.

At each locations 4 nos. of foundation bolts of size M20 are there to be fixed to the walls. Direct shear stress induced in each bolt (τ) is 81 kg/cm^2. Because of the moment the tensile load will come on the upper two bolts from the centre line and compressive load will come on two bolts. Tensile stress induced in the bolt is 93 kg/cm^2. Maximum principal stress induced in the bolt is 140 kg/cm^2. Allowable tensile stress of bolt for SA307 material is 1020 kg/cm^2 which is more than 140 kg/cm^2. Shear stress induced in the plate is 339 kg/cm^2, which is less than the allowable value of 510 kg/cm^2.

SPECIAL FABRICATION PROCESSES

The fabrication of collimator involved some advanced manufacturing techniques like Electric Discharge Machining (EDM) and Hard Chromium Plating. EDM was required to machine precise slits at accurate position on the collimating MS blocks to ensure continuity from one block to another and ensure a planar X-Ray fan beam within 50 micron accuracy. Hard Chrome Plating was utilized to coat MS blocks with non-corrosive coating which also adds to the surface hardness and low coefficient of friction.

MATERIAL OF SLIDE WAYS AND ALIGNMENT

The collimator after completely being mounted will be required to move in x, y, z direction and angularly so as to achieve desired shape of the X-Ray beam and to align it with X-ray beam coming from 9 MeV Accelerator. This movement had to be facilitated by either providing slide way strips below the MS blocks which should be able to sustain 5000 kg of compressive loads. The strip should also be well lubricated for free movement of the blocks. To achieve this, the material selection of this strip was very critical. The material had to be self lubricating as external lubrication to these strips would be cumbersome and also should be hard enough to bear huge compressive loads.

Thus, Phosphor-Bronze was found to be having very low coefficient of friction and was tested for bearing compressive loads of around 5 tons.

Frictional force required moving the collimator assembly of 5-ton weight approximately is given by the formula: $F = \mu R$, Where: F = frictional force required to move the collimator assembly, μ = Co-efficient of friction between the materials that is phosphorous bronze to steel (0.35), R = Normal reaction or weight acting vertically. Frictional force required to move the collimator assembly is 2020 kg. Bolts are accordingly selected to give x, y movement.

STATUS OF COMMISIONING

Collimator plate structure along with support structure is assembled at ECIL site. Movement of plate in x, y, z direction and angular movement is also checked.