KINEMATIC ANALYSIS AND EXPERIMENTAL VERIFICATION OF A ECCENTRIC WHEEL BASED PRECISION ALIGNMENT MECHANISM FOR LINAC

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Abstract

Eccentric Wheel based precision alignment system was designed [1] for the remote motorized alignment of proposed proton injector LINAC(SFDTL). As a part of the further development for the alignment and monitoring scheme, a menu driven alignment system is being developed. The paper describes a general kinematic equation (with base line tilt correction) based on the various parameters of the mechanism like eccentricity, wheel diameter, distance between the wheels and the diameter of the cylindrical accelerator component. Based on this equation the extent of the alignment range for the 4 degree of freedom is evaluated and analysis on some of the parameters variation and the theoretical accuracy/resolution is computed. For the same a computer program is written which can compute the various points for the each discrete position of the two motor combinations. The paper also describes the experimentally evaluated values of these positions (for the full extent of area) and the matching/comparison of the two data. These data now can be used for the movement computation required for alignment of the four motors (two front and two rear motors of the support structure).

1. INTRODUCTION

The performance of any accelerator relies on the accuracy of alignment system. The accuracy requirement of the alignment varies for type of accelerator and its application. The different components of LINAC (Magnets, RF accelerating structures and beam diagnostic devises) need to be at beam axis (at the mechanical axis of the structure) for accurate functioning, which is only possible by means of precision alignment. Many types of precision support and alignment systems like push-push screw adjuster, wedge jack adjuster, kinematic suspension using multi spherical joints (hexapod system), six strut system, CMPS jacks etc are in use for accelerator components. We are proposing an eccentric wheel based alignment system, which is also very precise, backlash free (backlash free range of angular movement is computed [2, 3]) and suitable for motorization (remote operation) for the proton injector LINAC project.

Motorized precision alignment system is used for remote alignment/ or alignment corrections. This remote alignment becomes essential for proton LINAC components of medium and high energy, because of residual radioactivity. Here we need very tight alignment accuracy for the stringent requirement of beam.

2. ECCENTRIC WHEEL BASED ALIGNMENT SYSTEM

2.1 System Description

Eccentric wheel based alignment system comprises of two eccentric wheels in the front and two on the rear of a support frame. The wheels are mounted on shafts and are rotated by stepper motor through worm and wheel reduction gear. This mechanism is designed to support a load of up to 200 kg at 400 mm diameter and 600mm length. It provides smooth motion, at the micron level. When the one eccentric wheel is rotated form 0 to – 360^o and the other wheel form –0^o to +360^o (or vice-versa, depending upon the initial position) it is possible to adjust the centre of the object within the area, very precisely. If wheel A is rotated to clockwise and the other anti clockwise by same amount the object can be lifted up. If both the wheels rotated anti clockwise the object can shifted to left and vice versa. With other combination of the movements (direction and the amount of the rotation) any point in the area can be reached (Fig. 1).

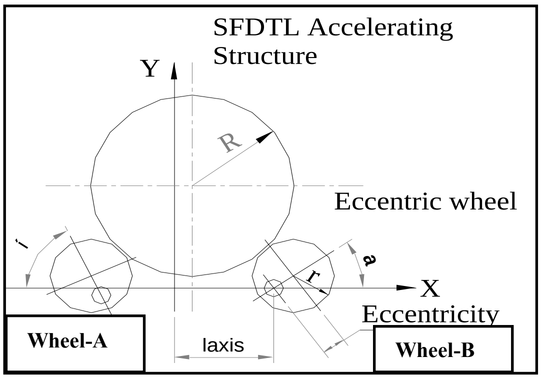
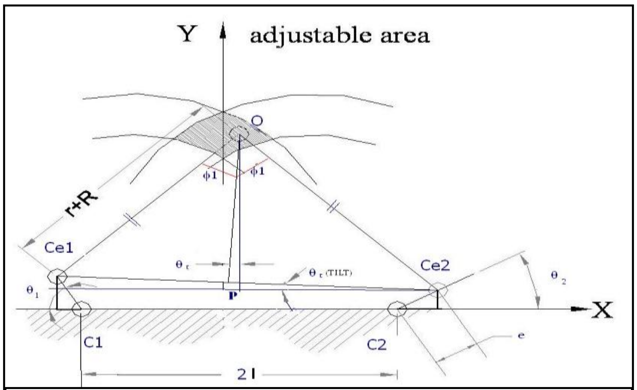


Fig. 1 Eccentric Wheel mechanism (schematic)

The area of the adjustment depends on the eccentricity of the two wheels (directly proportional) and the resolution is inversely proportional However, increasing the gear ratio can increase the resolution. Same mechanism on the other end of the accelerator structure, and with various combinations of the movements of the four eccentric wheels, one can get four degree of freedom for the alignment. The third rotational degree of freedom (i.e. ROLL) is not required / important for the circular accelerating structures like DTL/SDTL, whereas the linear longitudinal movement can be obtained by a separate linear translation stage.

2.2 Calculation of area of the resolution and adjustment

The stepper motor having 200 steps per revolution is attached with a worm and wheel gear (1:80). One step of the motor is corresponding to 1.8°, which is corresponding to (1.8/80=0.0225)° of the eccentric wheel. Multiply this angle ($\tan\theta \sim\theta$) in radian with the eccentricity we get maximum lift and hence minimum resolution 0.6 microns (theoretical)



C_1, C_2 = Center of the wheels (left & right) when e =0; C_{e1}, C_{e2} = Center of the wheels (left & right) for e eccentricity; C_1C_2 = 2*l; O = Center point of structure; R = Radius of the structure ; r = Radius of the wheel; $OC_{e1} = OC_{e2}$ =R + r; θ_1 = Angle of left wheel (anti-clock wise); θ_2 = Angle of right wheel (anti-clock wise), ;θ_t = Tilt Angle; Φ_1 = top angle

Fig. -2. The Mechanism Kinematics

The adjustment area of the alignment depends mainly on the eccentricity, radius of wheel, the distance between the wheel centers and the radius of support structure. Fig.-2 shows the details of the adjustment area using rotation of two wheels.

The expressions for the adjustment area in terms of geometric parameters are given as Δx and Δy. This is calculated taking tilt angle correction in considerations.

$\Delta x = l - \{ (R+r)\sin(\phi+ \theta_t) + e\cos\theta_1)$

$\Delta y = \{ (R+r)\cos(\phi+ \theta_t) + e\sin\theta_1)$

Where $\theta_t = \tan^{-1}\{(e\sin\theta_1 - e\sin\theta_2)/(2l - e\cos\theta_1 + e\cos\theta_2)\} = \tan^{-1}(p/b)$

$\phi = e\sin^{-1}\{\sqrt{(b^2+p^2)} /2(R+r)\}$

A Fortran program has been written to find out all combination of θ_1 and θ_2.The area generated for various eccentricities from 0.5 mm to 2.5 mm is plotted fig. 3(a).

Similarly effect of varying various mechanism parameters can also be computed using the algorithm and computer programme developed.

For comparison of calculated data and experimental data, an experiment was performed [1]. With a prototype having R = 190 mm (SFDTL Flange radius); r = 90 mm; e = 1.5 mm and $2l$ = 410 mm. Fig. 3(b) shows experimental measured values. There is a small difference in the theoretical and experimental, which can be corrected.

3. CONTROL FOR MOTORIZED SYSTEM

A menu driven control/ drive mechanism for 4 stepper motor is also under development and some work is already done [4]. Further remote motorised alignment system with laser based alignment/alignment monitoring work is also being developed for the long term alignment monitoring of LINAC components.

This alignment monitoring system will make use of stable laser for reference and position sensing device (PSD) for position sensing of each accelerator components, mounted at the front and rear. This will be used as feedback system for the menu driven control system.

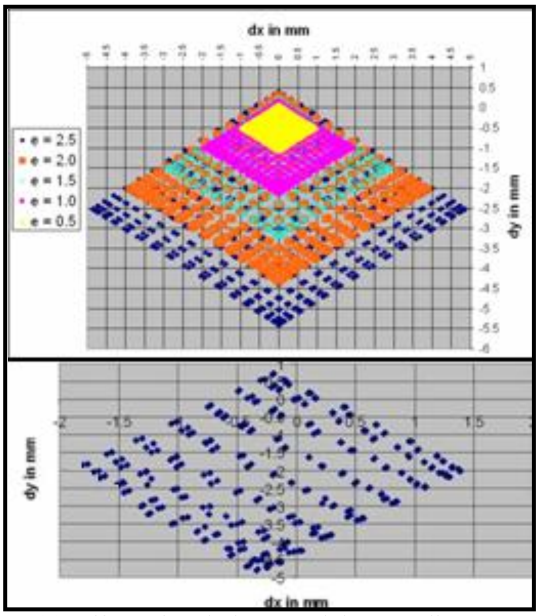


Fig. 3 (a) Effect of varied eccentricity on adjustments area, (b) Experimental measured data

4. CONCLUSIONS

Kinematic analysis of eccentric wheel based alignment monitoring system (with 4 degrees of freedom) is done. Based on these equations an algorithm and computer programme is also developed. The analysis now can be used to optimise the alignment system based on the accelerator component diameter and other parameters like wheel dia., eccentricity, distance between etc for the resolution, shape and range of the alignment area. The algorithm will also help in guidance for the movements of various motors for the motorised remote operation through menu driven control / drive system.

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