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Design, Fabrication and Analysis of Automatic Telescopic Mount

Gaurav V. Bhawde[1]
gauravbhawde@rediffmail.com

Akshay Kadam[2]
akshaykadam14@gmail.com

David Lobo[3]
David.lobo995@gmail.com

Roshan Gawade[4]
rgawade23@gmail.com

Shardul Mhatre[5]
www.gameboy23@gmail.com

Department of Mechanical Engineering,
St. John College of Engineering and Management, Palghar,
Maharashtra, India

***Abstract*- The major advantage of the project is the ease with which a celestial body may be tracked in the night sky. This gives us access to proper imaging and exploring new systems in the night sky. The telescope has an 8' aperture .This is achieved by attachment of worm-worm gear arrangement mounted of the shafts of the RA and Dec axes of the telescopic mount. To this a controlling system using PLC programmed with PLC language is used which is controlled by using an HMI. The project aims to have high accuracy and precision in object tracking. A Nema 23 Stepper motor with a 4.25 reduction gearbox has been selected. This arrangement is controlled by a 24V SMPS and 48V DC power supply. The project is economically affordable thus making it more available to the local enthusiasts.**

Index Terms – Equatorial Mount, RA and Dec axis, PLC, HMI, Nema 23 Motor, SMPS, gearbox, Celestial

I. INTRODUCTION

Automatic Equatorial Mount is made to automatically track celestial bodies in the night sky using a HMI and the entire process will be automated to obtain high end imagery and exposures ranging from 5 minutes to 6 hours easily.

A. Working

Automatic Equatorial Mount has been designed to be on two axes, Right Ascension and Declination axis specifically. The shafts are controlled by a worm and worm gear arrangement made upon them. The worm is controlled by a gear box which is given motion by a stepper motor of 27.2 RPM. This motion is reduced to 0.05 RPM from a 4.25:1 reduction ratio gearbox attached to the output shaft of the motor. This is then connected to the worm with the help of a bronze coupling arrangement. The motors are given Pulses by a PLC which are controlled by a programmed display custom manufactured. The Motors are given 48 V DC. The PLC is given 24V DC; both are different power supply units. Thus the shaft motion is controlled.

On the Axes of the shaft, perpendicular to the shaft is a scale for angular measurements for tracking celestial bodies using a reference. Once the Celestial object to be tracked is viewable from the telescope, the RPM from Maximum to the desired 0.05 RPM has been change. The RPM is specifically 0.05 or 1 degree in 4 minutes. This gives us the diameter of shaft 20mm; otherwise the shaft diameter changes causing problems. Polaris is a star that doesn't seem to move when viewing from the Earth. This is due to the fact that it is aligned with the axis of the Earth. So Polaris acts as a point from which one can easily trace other celestial bodies using their generally known RA and Dec angles.

II. AUTOMATIC TELESCOPE

A. Objectives

1. To fabricate and analyze the tracking of celestial bodies.
2. To find the accuracy with time of tracking and improving the accuracy.

B. Concepts

Angle: Angles are permissible in the range of 0^0 - 180^0 only on the RA- shaft. This is due to the hemisphere being 180^0 visible from any position on the earth usually. The DEC axis has full 360^0 rotation available to it.

Hours: The midpoint of the hours is 0 hours and before midnight its 23 hours and so on till afternoon 12o'clock. After midnight the hours are 1o'clock and so on till afternoon 12 and then its 13 hours and so on a 24 hour scale. Each hour has 15^0 in it. It is designated as $\omega=\pm15^0$.

Polaris: The Polaris is a star that doesn't seem to move when viewing from the Earth. This is due to the fact that it is aligned with the axis of the Earth. So Polaris acts as a point from which one can easily trace other celestial bodies using their generally known RA and Dec angles.

Effectiveness: The effectiveness is given by the trail marks occurring with respect to time of tracking of the object by the telescope. It has been done by placing a camera at the lens of the telescope and then continuously clicking pictures and then using external software for compiling them all together. This gives us a high exposure clear image of deep space.

C. Components Description

The body of the mount on the lower section is made up of mild steel. There are three legs which are supported additionally by attachment of horizontal supports from the central cylindrical frame. Above the frame there is housing of shafts and bearings for supporting them. The rubber foot can withstand up to 50Kilograms individually.

The shafts are selected of stainless steel for their high capacity to bear load and withstand the bending moment acting upon them. The motors preferred in this sensitive operation are stepper motors with a low RPM and a gear box. Stepper motor has coil windings that help enhance the smooth motion transmission without jerking the motion.

The PLC is a custom programmed unit that provides the designated RPM by relaying information to the motor controller that produces pulses for the designated RPM.

The power supply is for providing the proper supply to the PLC setup and the motors individually. The standard voltage of 230V AC is converted to 24V DC and 48V DC respectively.

Worm and worm gear are a special arrangement for constant motion. There is heat dissipation and no significant crushing load acting due to material being phosphor bronze. Bearings enable smooth motion transmission by making interference fit with the shaft and thus, remove the chances of impurities present in the actual hole for the shaft. Bearing used is needle bearing to withstand high radial load in our case.

TABLE 1

DETAIL OF WORM AND WORM GEAR

Worm Gear Diameter	70mm
Number of Teeth [Gear]	72
Angle between teeth[ϒ]	5.19^0
Face width [b]	10mm
Material	Phosphor Bronze

TABLE 2

DETAILS OF BEARING

Capacity	1850Kgf
Designation	NA04-SKF Bearing
Diameter	ID 20mm
Type	Needle Bearing

TABLE 3

DETAILS OF SHAFT

Shaft Length	330mm
Material	Stainless Steel
Diameter of Shaft	20mm

D. Working

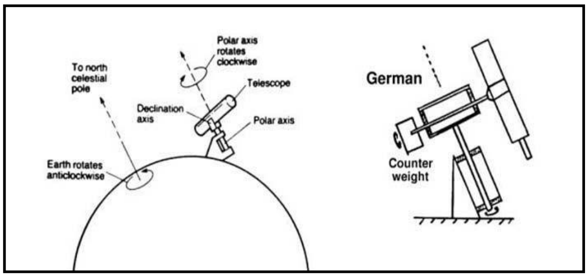

Figure 1. Working of Equatorial Mount

In the above figure it can be shown how the telescope focuses on a celestial body and tracks it in the night sky. The motion of RA Axis is opposite to the motion of the Earth through the night sky. The Dec axis is made collinear with the Polaris primarily.

To turn on the automation system, first turn on the 24V DC power supply and the 48V DC motor power supply. Then selected the designated body to be traced and align the telescope to the star with the help of motors at max speed. The speed is controlled using the display which is programmed by the manufacturer. Once the motors start getting the pulses they induce magnetic effect in the coil and the motion is set up upon the output shaft.

This output shaft has 27.2 RPM. This RPM is further reduced by a 4.25:1 by planetary reduction gearbox. This gearbox gives us 0.05 RPM. If there is need to move the telescope, it further adjusts the RPM for the motion. The shafts are lubricated with oil and the bearings are greased to protect from impurities. There is heat dissipation caused by the gears. There is a camera fit on the lens of the telescope which captures the deep space images connected to a laptop that gets the data feed constantly from it. In this manner the basic functioning is started. This setup can stay up to 180^0 from start to end of the process, but that is the maximum viewable hemisphere so that is the limitation of it. The Dec shaft can rotate 360^0 if needed.

Figure 2. Experimental Setup of the Mount

E. Observation

Figure 3. 5 minute exposure image of Arcturus

It can be seen in the above figure that the starting at the starting position after a five minute exposure the image that obtained is very stable and is on the mark as expected. This image was tracked for 5 minutes. As the exposure was 5 minutes the image is seen clearly and the surrounding gases and deeper objects are not visible.

TABLE 4

LOCATION AND EXPOSURE OF IMAGE

RA	14^h 15^m 39.7^s
Dec	+19° 10′ 56″
Exposure time	2 minutes / picture

F. Analysis of Major Components

TABLE 4

MATERIAL PROPERTIES

Material Selection: Phosphor Bronze		
	[σ_c]	[σ_b]
Worm	1900 kgf/cm^2	900 kgf/cm^2
Worm Gear	1900 kgf/cm^2	900 kgf/cm^2

TABLE 5

GEAR DIMENSION AND PROPERTIES

From PSG 8.47 Table36A			
Z	z	q	m
1	72	18	5

On market survey and checking catalogues for the selection of motor capable of rotating the telescope with the speed of the Earth the main factor that comes into consideration is the driving speed of the shaft. Generally all motors are designed for high torque transmission with a high power supply. If a DC motor would've been use then a spur gear would've come into implementation. When spur gears engage or disengage there is a jerk that moves the telescopes which eliminates the selection of spur gear or DC motor drive regardless of its speed of rotation.

On market survey, founds a lot of catalogues and select a suitable motor with the least driving speed which can further be reduced by use of reduction gear drive at the exit of stepper motors driving shaft. Thus reducing the total output as per our requirement.

All of the components used have been analyzed in ANSYS software before their fabrication or purchase to estimate the load that would be acting upon them to get the general idea if the component would be actually be able to sustain it or should there be any changes made to dimensions or to choose a different material respectively.

Major Force Diagrams acting upon RA and Dec Shafts:

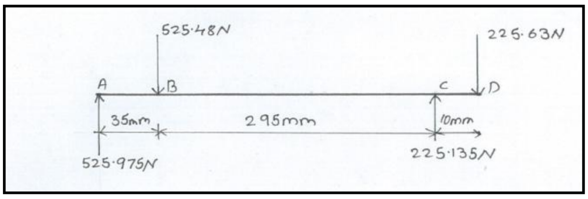

Figure 3. Vertical Force Diagram For RA shaft

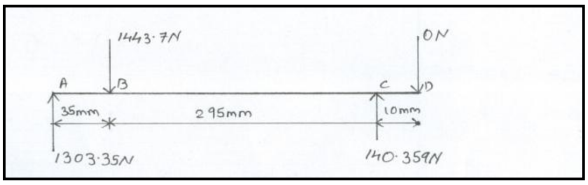

Figure 4. Horizontal Force Diagram for RA shaft

TABLE 6

BENDING MOMENTS ON RA SHAFT VERTICALLY

BM_A	525.975 Nmm
BM_B	525.48 Nmm
BM_C	225.135 Nmm
BM_D	225.63 Nmm

TABLE 7

BENDING MOMENTS ON RA SHAFT HORIZONTALLY

BM_A	1303.35 N-mm
BM_B	1443.73 N-mm
BM_C	140.359 N-mm
BM_D	0 N-mm

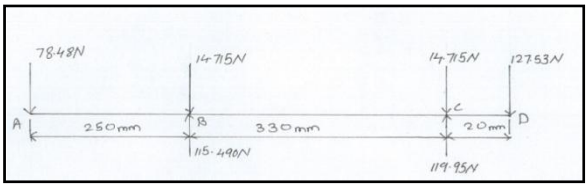

Figure 5. Vertical Force Diagram for Dec Shaft

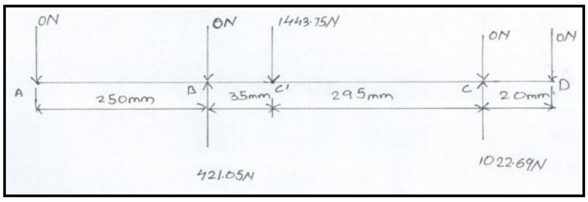

Figure 6. Horizontal Force Diagram for Dec Shaft

TABLE 8

BENDING MOMENTS OF DEC SHAFT VERTICALLY

BM_A =	9633.57 Nmm
BM_B =	9807.17 Nmm
BM_C =	2444.365 Nmm
BM_D =	127.53 Nmm

TABLE 9

BENDING MOMENTS OF DEC SHAFT HORIZONTALLY

BM_A =	3000000 Nmm
BM_B =	287149 Nmm
BM_C =	1022.69 Nmm
BM_D =	0 Nmm

Selected Diameters for the Ra and Dec shaft are 20mm respectively.

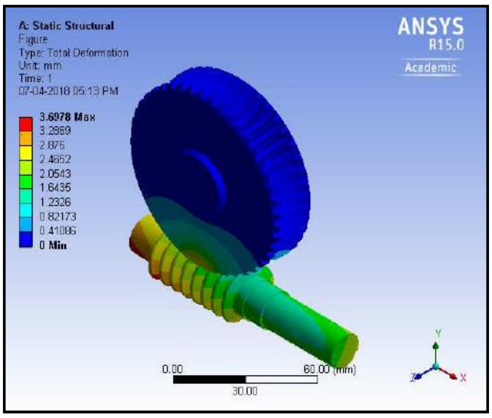

Figure 7. ANSYS Analysis of Worm and Worm Gear

In the above figure, see the forces acting on the Worm-Gear from the worm. These forces are shows minimum deformation upon the worm-gear despite the force transmission. The material of the Worm and Gear is phosphor bronze and have a very high density and yield strength and the ability to undergo deformation is comparatively much less.

This goes on to prove that our selected gear and worm material has comparatively are successfully able to withstand the load and can thus be selected for motion transmission. The force is distributed to the worm from the transmission in the form of horizontally distributed force

III. Result and Conclusion

The motor RPM is 27.12. The desired RPM on shaft is 0.05 which is successfully available after transmission from worm to worm gear on both the shafts. This testing is done in normal atmospheric conditions.

There is constant motion available when the telescope moves in any of the required directions. The objective is focused properly in the lens of the telescope and is viewable from the lens of the camera.

When readings were taken for more objects it was seen that there is minor jerking occurring leading to distortion of images which is to be eliminated. This occurs when the telescope moves from centre 0hours to left or right maximum side.

IV. Acknowledgement

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