Postprint: Study on Payload Deformation of the NVST Terminal Instrument Derotation Platform

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Abstract

This study investigates the load-induced deformation of the upper platform of the derotation platform for the terminal instruments of the 1-meter New Vacuum Solar Telescope (NVST). Microscopic deformations are detected by measuring the displacement of a detection laser spot on a CCD detector. During the experiment, the laser source is fixed in a stable region and directed toward the CCD detector in the measurement region. Spot centroid data on the CCD detector target surface is calculated using a centroid algorithm; variations in centroid position reflect the deformation of the measured region, with only deformations in the direction of gravity being studied. Through multiple experiments and ANSYS simulations, it was found that the significant inconsistency in deformation in the gravity direction during forward and reverse rotation occurring in the 80° to 200° region at the three cantilever edge positions of the upper platform is largely caused by the combined effect of two factors: misalignment between the drive plane and the bearing positioning plane, and the forward and reverse roller sets not being strictly aligned toward the rotary table center. Among the three cantilevers, one exhibits significant deformation and load sensitivity across multiple rotation regions, while another shows load sensitivity in partial regions; both are primarily caused by poor connection stiffness with the rotary table center.

Full Text

Preamble

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Terminal Instrument Derotator Platform Load Deformation Study of the New Vacuum Solar Telescope

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Abstract

This study investigates the load deformation of the upper platform of the terminal instrument derotator platform on the New Vacuum Solar Telescope (NVST). A detection method employing laser spot displacement on a detector is utilized to measure minute deformations. During experiments, the laser source is fixed in a stable region and directed toward the measurement area. The centroid of the spot on the detector target is computed using a centroid algorithm, where variations in centroid position reflect the deformation of the measured region. Only deformation in the direction of gravity is studied.

Through multiple experimental trials and ANSYS simulations, it is found that the significant inconsistency in deformation between forward and reverse rotations in the 80°–200° range is largely caused by two factors: the misalignment between the drive plane and bearing positioning plane, and the fact that the forward and reverse roller groups are not strictly pointed toward the turntable center. Among the three cantilevers, one exhibits obvious deformation in multiple rotation regions and is sensitive to load, while another shows load sensitivity in partial regions; both are primarily attributed to poor connection stiffness with the turntable center.

Keywords: derotator platform deformation; centroid algorithm; NVST

1. Introduction

For telescopes with fixed Nasmyth or Coude foci, field rotation is relatively small when observing a single point source. However, when observing extended fields, all such systems suffer from field rotation issues that require the object to remain fixed relative to the detector at the focal plane. To counteract image field rotation, platform-based derotation is typically implemented through hardware or software methods, including optical element derotation and post-processing image derotation.

The Sun, as the nearest star to Earth, dominates solar-terrestrial space relationships and serves as an indispensable research facility for solar physics. Among currently operational altitude-azimuth solar telescopes, many employ platform-based derotation, including the Chinese Giant Solar Telescope (CGST) and Chinese Large Solar Telescope (CLST) currently under development in China, both of which consider platform derotation approaches. shows the derotation methods employed by major solar telescopes worldwide.

The precision of backend instruments mounted on the derotator platform is crucial for imaging observations. However, no prior research has been reported on derotator platform deformation for large solar telescopes. This paper employs a method using a laser source directed at a detector to calculate deformation of the measured region based on centroid variations, investigating the load deformation issue on the NVST terminal instrument derotator platform.

2. Experimental Method and Principle

The deformation detection principle utilizes laser spot displacement on a detector to measure structural deformation of large platforms. The centroid variation on the detector target is calculated to determine the deformation of the measured region. During experiments, the laser source is fixed at the center of the turntable and directed toward the CCD camera mounted at the edge of the cantilever on the peripheral platform. A neutral density filter is added to reduce light intensity. Only the deformation of the cantilever edge region is studied. The NVST spectrograph platform can only rotate through a limited range, so three cantilever conditions are superimposed to represent the entire platform.

3. Experimental Instruments

The experimental instruments are as follows:

Laser: MRL-III-671-50 mW, Changchun New Industries Optoelectronics Technology Co., Ltd.
CCD: pco.4000, PCO AG
Neutral Density Filter: UPAM OD4, Chengdu Super Pure Technology Co., Ltd.

shows the laser beam stability for the experiment. To verify the sensitivity of the experimental method, the derotator platform cantilever was manually pushed to test its sensitivity to impact loads. The signal sensitivity meets requirements, with the X-axis (gravity direction) response far exceeding the Y-axis response.

4. Data Preprocessing

The collected files are 2672×4008 pixels. Since the actual laser spot is small and centroid variation is minimal, a 1000×1000 pixel region is processed to improve computational efficiency. To enhance signal-to-noise ratio, noise filtering is applied with specific parameters determined according to each experimental condition. The final centroid data of the spot is calculated after determining background noise.

5. Experimental Results and Analysis

5.1 Static and Dynamic Data Collection

Static centroid data at different angles were collected for multiple operating conditions to analyze the effects of speed and load. Dynamic data for both forward and reverse rotations were acquired to analyze drive force effects. The mechanical simulation of centroid variation trends throughout the rotation process was performed using ANSYS.

5.2 Cantilever Deformation Characteristics

The three cantilevers exhibit different load sensitivities. When a 70 kg load is applied at the cantilever edge, the deformation is 288 m (measured) versus 315 m (ANSYS simulation), showing good agreement. [Figure 3: see original paper] shows the centroid data for each cantilever at different angles with and without load. presents the mean centroid variation data for the three cantilevers at different angles under loaded and unloaded conditions.

Superposition of static and dynamic data reveals that in most rotation regions, the static and dynamic centroid data for all three cantilevers overlay well. However, in the 0°–100° region, the overlay is poor, suggesting that drive force and other factors affect stress-strain in this region. The 80°–200° region shows obvious peaks and forward/reverse inconsistency.

5.3 Forward/Reverse Rotation Inconsistency

Significant inconsistency between forward and reverse rotation appears in the 80°–200° range. [Figure 4: see original paper] shows the superposition of static and dynamic data (upper curves represent loaded data) and comparative analysis of forward and reverse rotation. [Figure 5: see original paper] compares load effects during forward and reverse rotation, showing that cable drag and speed have minimal impact on experimental results.

The primary cause is the misalignment between the drive plane and bearing positioning plane. The NVST platform rotates via rollers arranged between cantilevers. Due to assembly gaps and environmental temperature, rollers exhibit radial forces either toward or away from the center. The distance between the two planes provides a force arm, and the combination of force and arm generates a torsional moment about the horizontal axis, ultimately causing gravity-direction deformation of the cantilevers.

5.4 ANSYS Simulation

Since the actual instrument layout parameters are unknown, reliable simulation is impossible. Therefore, the working condition of cantilever 2 is simulated with the upper platform stationary. Roller position movement through certain angles simulates platform rotation to corresponding positions. The radial forces of four rollers can combine in four scenarios. [Figure 6: see original paper] shows schematic diagrams of roller radial force components and the upper platform positioning/drive planes. [Figure 7: see original paper] shows the simulation of platform rotation via roller position change and the simulation results. When forward rollers point toward the center and reverse rollers point away, the forward/reverse deformation inconsistency matches the simulation trend well.

5.5 Comprehensive Analysis

The comprehensive analysis shows that the 80°-200° forward/reverse inconsistency is mainly caused by two aspects: (1) the misalignment between drive and bearing planes, where radial components of drive force create additional torsional moments causing strain deformation; and (2) opposite radial force directions from forward and reverse rollers. The 0°-100° region deviation is affected by drive forces and other factors.

One cantilever shows abnormal centroid variation trends in multiple intervals (195°-215°, 285°-305°, 300°-330°) with peak values of 250 m, indicating impact loads and poor connection stiffness with the turntable. The load sensitivity ranking is cantilever 2 > 3 > 1, which correlates with stiffness conditions. The instrument layout on the upper platform should prioritize cantilever 1 for improved stability.

6. Conclusion

This study establishes a simple optical path with a laser source directed at a detector to collect deformation data of the telescope derotator platform under multiple operating conditions. The 80°-200° region shows obvious peaks and forward/reverse inconsistency, with deformations of approximately 250 m —equivalent to nearly 30 pixels on the target surface, which severely affects imaging quality. The analysis identifies the main causes of upper platform deformation: misalignment between drive and bearing planes, and the fact that roller groups are not strictly pointed toward the turntable center. Load effects on cantilevers in the 0°-100° region are also observed. ANSYS simulations confirm these findings. This research provides valuable reference for subsequent instrument alignment and platform improvement.

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Note: Figure translations are in progress. See original paper for figures.