Optical Characterization of Concentrating Solar Power Technologies at NREL

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1. Abstract

Concentrating Solar Power Technology is being developed both in the U.S. and internationally. These projects include parabolic trough, dish/Stirling engine and concentrating photovoltaic technologies. In addition to these new projects, parabolic trough power plants totaling approximately 350 MW already exist within the U.S. and have operated for close to 20 years. As such, the status of the technology exists within several different phases. Theses phases include R&D, manufacturing/installation and operations/maintenance. One aspect of successful deployment and operation of this technology is achieving and maintaining optical performance. Different optical tools are needed to improve initial designs, provide quality control during manufacture/assembly and maintain performance during operation. This poster session highlights some of these tools as they have been developed and used by the National Renewable Energy Laboratory to further the deployment of concentrating solar power.

2. CSP Technology Phases

- Development
  - R&D directed at maximizing performance/cost ratio
  - Requires testing tool(s) that provide detailed data on mirror contour, mirror panel positioning
- Manufacture/Installation
  - QC testing of mirror panels (statistical sampling)
  - Module assembly
  - Requires fast, relatively simple optical characterization to reveal problems & fix
- Maintenance/Operation
  - Many contributors to optical performance (e.g. specularity, mirror distortion, dirt, receiver shape/position)
  - Large fields require simple, fast, effective tools to understand/fix problems & maximize performance

3. Optical Characterization Areas

- Mirror Optical Accuracy
  - Mirror contour
  - Mirror specularity
- Mirror Panel Alignment
  - Tilt
  - Position
- Receiver Positioning

- Point: Different tools meet needs of each phase of technology deployment.

4. Optical Characterization Methods

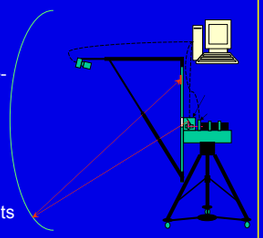
- Distant Observer Techniques
  - Receiver is imaged, thus couples receiver position/shape to concentrator optics
  - Potential for large mirror areas (module level) to be characterized quickly; does not provide point by point surface measurement (i.e. suited to fast module/mirror panel/receiver alignment)
  - Examples: Theoretical Overlay Photographic Alignment System (TOP)
- Photogrammetry
  - Characterizes surface as Z(x,y), not slope which provides more optical information
  - Minimal equipment required (still camera/reference grid/software)
  - Potential for large mirror areas to characterized this way
  - Requires prior surface preparation with reference grid

5. Optical Characterization Methods (cont.)

- Laser Ray Tracing
  - Measures slope (dZ/dY, dZ/dX) as 1st order effect
  - Statistical and point by point information provided relative to desired surface
  - Iterative process yields best fit surface equation
  - High accuracy and precision (< 0.1 mrad)
  - Fast
  - Practical test sizes limited to full aperture height X one mirror panel width
  - Suited to mirror development and QC for mirror manufacturing
  - Example: Video Scanning Hartmann Optical Test (VSHOT)

6. Video Scanning Hartmann Optical Test

- Originally designed for point-focus concentrators
- Adapted for line-focus optics (samples one mirror panel width at a time)
- Measures bi-directional surface slope, fits data to user defined shape, reports best fit shape and errors relative to that shape

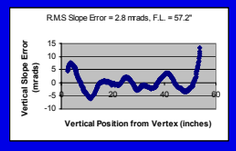


7. VSHOT Prototype Trough Test

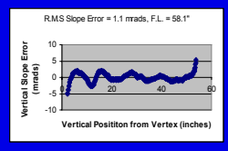
8. VSHOT Prototype Trough Test (cont.)

VSHOT as trough development tool
- Cost versus performance
- Mirror panel development
  - Optical surface accuracy

Slope error profile of 1st generation developmental mirror



Improved slope error profile of 2nd generation developmental mirror

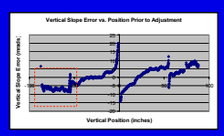


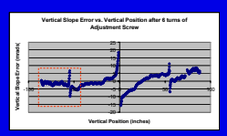
9. VSHOT Commercial Trough Test

10. VSHOT Commercial Trough Test (cont.)

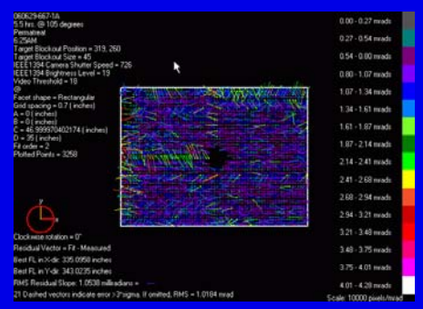
VSHOT as development and manufacturing/installation tool (Solargenix/Starnet)
- Mirror position/tilt/deformation on module support structure

Example: Correction of lower panel tilt





11. VSHOT Test of Mirror Panels for 25kW Dish/Stirling System



12. Summary

- Optical Testing Critical to all phases of CSP Deployment
- Different tools needed for different phases
- VSHOT is one tool which cuts across all technologies and phases.

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