

Methods and Results of Reducing Following Error in the LLNL Large Optic Diamond Turning Machine

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The USAF Integrated Flight Experiment (IFX) Project is part of the development of the Space Based Laser (SBL) Program. The LLNL Large Optics Diamond Turning Machine (LODTM) is responsible for diamond turning the aspheric laser cavity mirrors. These large optics must be manufactured to micro-inch tolerances. The optics are made of silicon to minimize cooling requirements and weight in the SBL. Diamond turning silicon presents many challenges to the LODTM; one of which is silicon's anisotropic property. When cutting these cones shaped optics, the machine sees many different crystallographic planes of the silicon. These planes present different degrees of material hardness. The tool is held in position but it experiences a force variation as it cuts across the different crystallographic planes. This force variation is reflected back into the machine control system and presents a dynamic disturbance that increases the servo system following error. The affect of this error is to cut a part that is not round but "squareish", i.e. at the micro-inch level.

Two methods were used to reduce the following error or increase the machine dynamic stiffness. Each method relies on the fact that the cutting process is cyclic. The two methods are described below.

- Method one increases the machine dynamic stiffness and reduces the following error by increasing the servo system bandwidth and the loop gain at the disturbance frequency. The paper discusses how the servo compensation filters were designed to accomplish this goal. The reduction of following error by this method proved very successful and is reported in the paper.
- Method two uses an adaptation of a proprietary controller developed by the Structural Dynamics group of the Lockheed Martin Corporation (LM). The system, know as the DECS controller, works in addition to the present LODTM control system. It observes the LODTM following error and generates a correction signal that adaptively removes any cyclic following error. The DECS controller was originally developed for dither control of telescope IR secondary mirrors. (The Keck telescope and some other observatory telescopes use this system.) The particular DECS algorithm is not discussed in the paper, as it is a proprietary algorithm of LM, however, the results of applying this technology to the LODTM is presented in the paper.

Together, both of these methods have reduced the LODTM position following error to the required micro-inch tolerances. The following error reduction has been shown even at relatively high disturbance frequencies with respect to the servo system bandwidth. Applying these two methods to the LODTM, the machine control system [2] following error is reduced to a level that no longer contributes to part contour error. With essentially no control system error, additional process issues and machine error sources have been identified.

[1] Donaldson, R.R. and Patterson, S. R., "Design and Construction of a Large Vertical Axis Diamond Turning Machine", SPIE's 27th Annual International Technical Symposium and Instrument Display; Aug. 1983

[2] McCue, Howard K., "The Motion Control System for the Large Optics Diamond Turning Machine (LODTM)", SPIE's 27th Annual International Technical Symposium and Instrument Display; Aug. 1983

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