A General Tool for the Design and Analysis of Stressed Optic Polishing

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Abstract: SigFit, a general tool for the design and analysis of stressed optic polishing is presented. SigFit will determine the number, location, and stroke magnitude for actuators for minimum surface error. Many options exist for combining test and analysis data.
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1. Introduction

Stressed optic polishing is a usful tool for generating large segmented mirrors [1]. SigFit [2], a general tool for the design and analysis of stressed optic polishing is presented. For a given mirror blank design and desired finished shape, SigFit will determine the optimum number of actuators, their optimum locations, and actuator stroke magnitudes for a minimum figure error. Because it is finite element based tool, SigFit will work with solid or lightweight optics of any shape, and can incorporate the reaction structure stiffness and design. During the polishing process, test interferogram data may be input and the updated actuator stroke determined.

2. Input Desired Surface

The desired figure of the full primary mirror is determined by the optical design of a telescope. For a segmented mirror, this global figure must be represented by each individual off-axis segment. SigFit offers an off-axis capability for this case. In other applications, the desired surface may be input to SigFit via surface polynomials (Zernike or XY) or rectangular array interferogram files

3. Actuator solution for given set

The finite element model of the mirror (optionally including the reaction structure) is excercised to determine the actuator influence funtions. The actuators may be any combination of applied forces, moments, or displacements. The solution for the actuator strokes is straightforward to minimize surface RMS [3]. Starting with the 2006 version of SigFit, the user may specify a fraction of the RMS total based on slope control, relative to displacement control. SigFit also has stroke limit analysis capability. Even when some actuators reach a limit, others may be able to compensate in the control of the surface.

4. Determining actuator number & location via genetic optimization

Early in a design, the optimum number and location of actuators must be determined. A genetic optimization algorithm has been incorporated into SigFit to find the optimum actuator locations [4]. First, the analyst must pick a series of candidate actuator locations and create the actuator influence functions within an FEA program. Within SigFit, the analyst picks a given number (N) of actuators to be present in the final design. SigFit uses the genetic algorithm to determine the "best" set of N actuators and the resulting surface accuracy. By making several runs with different values of N, curves of surface accuracy vs. N can be determined. As a user option, some actuators may be required at specific locations while the other locations are open to design. Also, the user may specify that actuators occur as groups, thus enforcing a predetermined symmetry in the final design.

An example mirror array for which stressed optic polishing is to be used is shown in Figure 1. The optical prescription is such that the medium grey petals have a significantly different shape than the dark grey petals. The best nine actuator locations while enforcing symmetry about the radial axis of each petal is to be found. For the purposes of this example we show the development of the optimum actuator layouts for the medium grey petals and the dark grey petals only.

After optimization of the actuator locations through the use of SigFit, the actuated surface for both petals is within 94.5% of the desired optical prescription as measured by surface RMS and within 92.3% as measured by peak-to-valley surface. The actuator layouts for each petal are shown in Figure 2.

By increasing the number of allowed actuators in the design optimization, the performance can be further improved as shown in Figure 3.

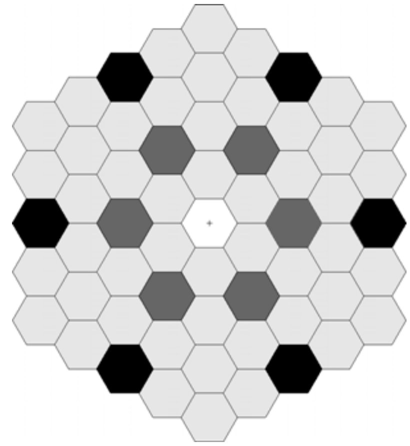
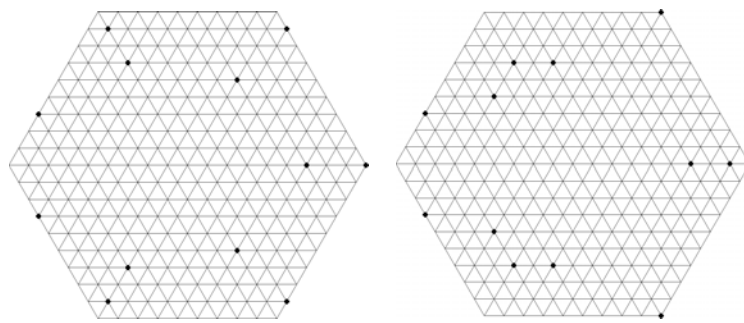


Figure 1: Array of petals for which stressed optic polishing is performed. Only medium grey and dark grey petals were considered for the purposes of this paper.

5. Output options

A variety of output options exist. The actuated residual surface is typically fit with polynomials (Zernike, XY, aspheric) which may then be sent to optics programs such as Code V, Zemax, or Oslo in their native format. Alternatively, the data may be presented as rectangular arrays in interferogram format. The final surface is also written to plot files for the finite element model. Finite element programs and post-processors supported include Nastran [5], Ansys [6], Cosmos, Patran, and Femap.



(a) (b)

Figure 2: Optimum actuator layouts for stressed optic polishing using 3 fixed location displacement actuators and 9 variable location actuators; (a) light grey petals shown in Figure 1; (b) dark grey petals shown in Figure 1.

6. Combining with Test Data

During the polishing process the optic is usually tested interferometrically. The test interferogram can be input to SigFit for a calculation of new actuator strokes. Often, this is combined in SigFit with a 1g backout determined from a finite element model of the test setup, including the test fixture and reaction structure, if currently attached. Test data may be linearly combined (added, differenced, etc) with other test or analysis data within SigFit, even if the test data is from different array sizes, locations, orientation, format, or wavelength. All data is interpolated on to the finite element model before combination, allowing test and analysis results to be easily combined.

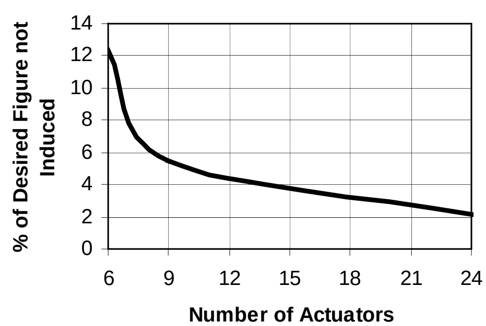


Figure 3: % Figure not captured by stressed optic vs. number of actuators

7. Lightweight optics optimization

SigFit's optimization interface to Nastran's solution 200 has been often used to optimize the mirror designs themselves to obtain desired adaptive control behavior [7]. The 1g surface response of a typical lightweight mirror shows "poke-thru" at the mount locations which can be mitigated by local stiffening. Since the same mount "poke-thru" occurs for polishing actuators, a lightweight mirror can exhibit improved stress polishing by incorporating the actuator locations in the mirror optimization to include local stiffening. Any variation in core stiffness will be included in the actuator influence functions for the adaptive control analysis. A recent enhancement includes SigFit's DRESP3 support which allows the actuated surface RMS from SigFit to be a design objective or constraint in MSC.Nastran [8]. With this response, MSC.Nastran's optimization will stiffen locally as allowed.

8. Summary

SigFit, a general purpose tool, has been presented to assist in stressed optic polishing. The genetic optimization feature will help designers answer the troubling questions of how many actuators to use and where should they be located. Because it is finite element based, SigFit will work with solid or lightweight optics of any shape, and can incorporate the reaction structure stiffness and design. During the polishing process, test interferogram data may be input and the updated actuator stroke determined. SigFit can also be used to optimize lightweight mirrors for polishing, as well as mounting. The user has several options for input and output to allow combining of test and analysis data.

9. References

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