GEMINI
8-M Telescopes
Project

TN-O-G0003

Effects on Surface Figure Due to Random Error in Support Actuator Forces for an 8-m Primary Mirror

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ABSTRACT

The effects of random errors of the support actuator force set on the optical surface distortion were investigated. The random force error set was assumed to have the following characteristics: (1) Gaussian distribution, (2) the maximum force error of 0.5 Newtons (three sigma force magnitude), and (3) the total number of 120 sampling data at the optimized support locations. RMS surface figures were estimated using six typical random cases for a hydraulic whiffle-tree support system. Two hydraulic systems, three-zone and six-zone whiffle-trees, are also considered in the surface figure evaluations. The objective of this study is to quantify the optical surface distortion due to the random errors in the actuator force set.

INTRODUCTION

The beauty of the active optics support system is that the optical surface figure can be controlled by the force actuators at the back of the mirror. Theoretically, the optical surface distortions introduced by mechanical or thermal input can be faithfully described, provided an infinite number of actuator supports are employed. In practice however, the optical surface variations are measured or described over a uniform grid which are commonly limited by the hardware and/or software. With the help of numerical implementation, the surface distortion can be adequately described by a finite number of the back supports. A least square fitting scheme is widely accepted for the numerical analysis.

The I-DEAS program was employed for the finite element analyses, and thin-shell elements were utilized to represent the meniscus primary mirror model as illustrated in **Figure 1.** Structural deflections from the mirror model were implemented in terms of the optical characteristics. A parametric study was previously performed to determine the optimal support system which implies the optimum number of the support actuators and their locations.

A total of 120 optimized supports were defined, and the support pattern is shown in **Figure 2.** Also illustrated is a proposed support arrangement of a six-zone hydraulic whiffle-tree defining system. The current support concept also allows to switch the six-zone system to a three-zone whiffle-tree system by connecting the two adjacent zones.

The objective of this study is to quantify the optical surface distortion due to random errors in the actuator force set. Effects on the optical figure based upon the two whiffle-tree defining systems are also investigated.

RANDOM FORCE SET

Every design parameter has a certain level of error, whether it is small or not. There also exists a manufacturing uncertainty, in other words, manufacturing tolerance. These kinds of uncertainties are interpreted as random errors under a common statistical term. As the current concept for the force actuators of the primary mirror, each actuator is designed for a maxim load capacity of 500 Newtons. An accuracy of one part per thousand on the maximum capacity for the support actuator, in practical applications, is acceptable for the current primary mirror back support system.

A set of random force errors in a probabilistic distribution with a single standard deviation (I sigma) was generated. This random force distribution is assumed to have the following probabilistic characteristics: (1) a Gaussian distribution, (2) a maximum force amplitude of 0.5 Newtons (three sigma force magnitude), and (3) a total number of 120 sampling data at the optimized support locations.

The normal random force error distribution includes a full range of force amplitude (approximately the limits of ± 3 sigma). For simplicity, **Table 1** lists a normalized random force set, normalized by the maximum amplitude, with ± 3 sigma distribution over the 120 sampling points. A proper scaling factor on the force set will be applied to achieve the manufacturing tolerance of the force actuators (0.5 Newtons maximum).

OPTICAL SURFACE DEFORMATION

A static analysis was performed for the response of the meniscus primary mirror to the random force errors in a six-zone hydraulic whiffle-tree defining system. In order to investigate the effect on the optical deformations due to different random loading conditions, six random cases were considered. Two of the six cases were considered as extreme loading conditions.

In the best of the two-limit cases, the largest forces were placed at the centers of the support zones so that the least amount of the surface error occurs. In the worst case, the largest forces were at the outer edge of the mirror along the borders of the each zone. In the other four cases, the random force set is placed in random arrangement over the six zones.

Finite element analyses were conducted for the primary mirror subjected to a set of random force errors supported by a six-zone whiffle-tree defining system. Typical optical surface contour map from I-DEAS for a random force set is shown in **Figure 3.** The contour map represents the optical distortion as a response of the normalized random force set in Gaussian distribution with ± 3 sigma amplitude. The evaluation of the optical performance for the random case was made. Encircled energy distribution and a plot of the point spread function are shown in **Figures 4 and 5,** respectively. For this particular case the diameters of the encircled energy are 0.0653 and 0.1985 arc seconds at 50% and 85% energy concentrations, respectively.

The proposed concept of the support system is also designed for a three-zone whiffle-tree defining system by connecting the two adjacent zones of the six-zone system. Similar investigation was performed for the three-zone system, and the results compared. **Table 2** lists the evaluations of the optical performance of the primary mirror for the two different support systems. The optical surface distortions for the six random cases with both support systems are shown in **Figures 6 through 11.** For example, Figure 6(a) illustrates the optical distortion for random case I based on a six-zone support system, whereas Figure 6(b) for the same random case based on a three-zone support system.

The surface figures for the six-zone support system vary with the loading cases. No pattern exists on the optical distortion. However there is a pattern on the surface figure for the three-zone support system. The shape is most likely an astigmatism.

SUMMARY AND CONCLUSIONS

Through performing a parametric study on the effects of random errors in the support actuator forces for the primary mirror, the following conclusions were drawn:

1. A program was developed to generate a set of random forces in Gaussian distribution.

2. Surface RMS distortion due to random force errors is relatively small compared to the other design parameters. Its extreme is approximately an order of 4.5 NM for a six-zone whiffle-tree defining support system.

3. As expected the surface distortion due to a random force set for a three-zone whiffle-tree defining support system is most likely an astigmatism.

4. Ratio of the surface errors of the primary mirror between the six-zone system and the three-zone system is in a range from 2.3 to 7.1 (Table 2).

REFERENCES

1. Press, W. H., et al., "Numerical Recipes," Cambridge University Press, 1987.

2. "I-DEAS", Structural Dynamics Research Corporation, 1990.

3. "CODE V", Optical Research Associates, Pasadena, California, 1991.

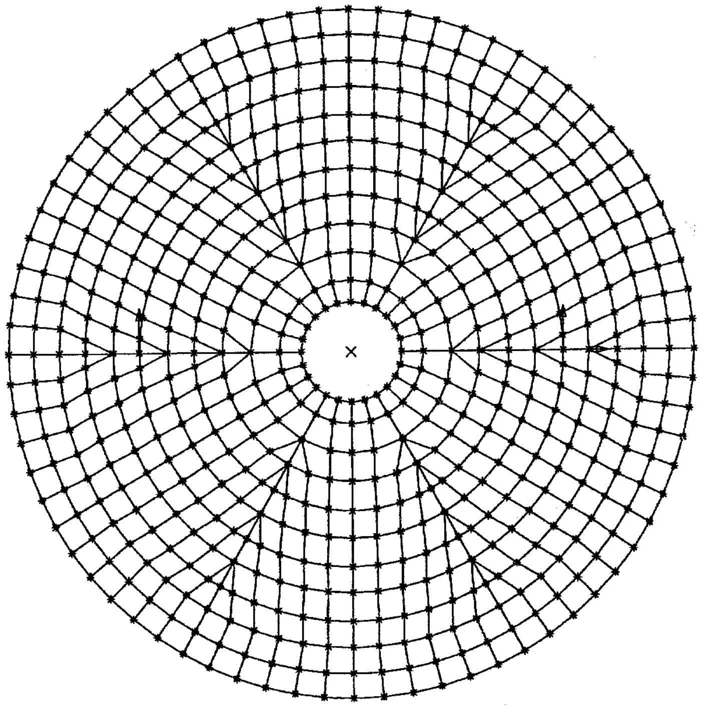


Figure 1. Finite element model of the primary mirror.

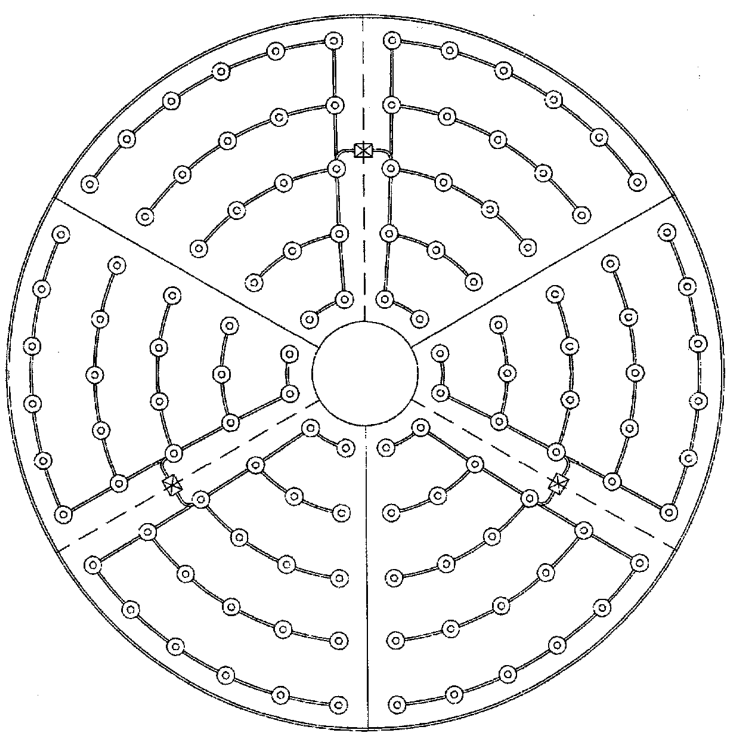


Figure 2. Six-zone hydraulic whiffle-tree defining support system

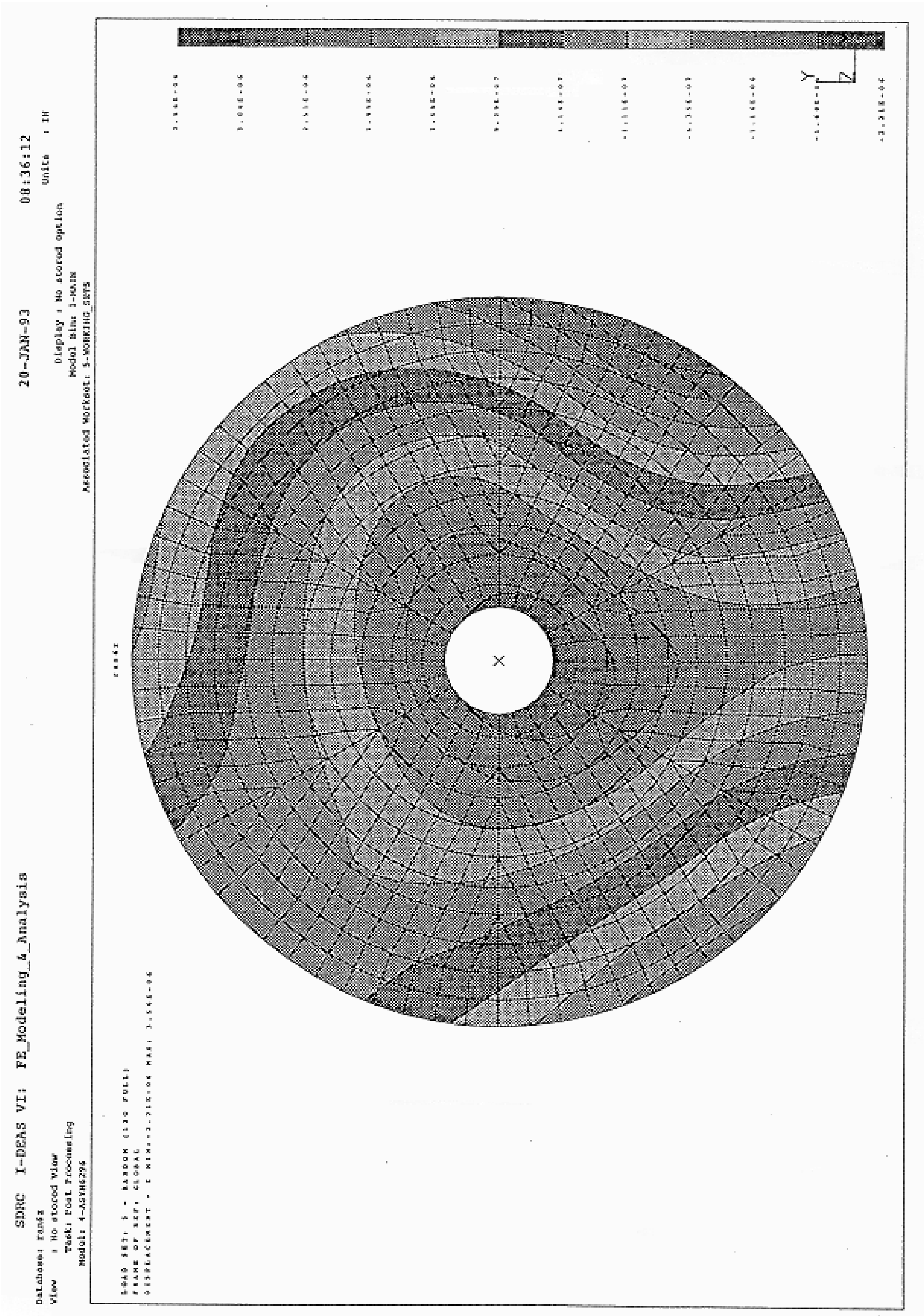


Figure 3. Typical surface distortion due to random force errors

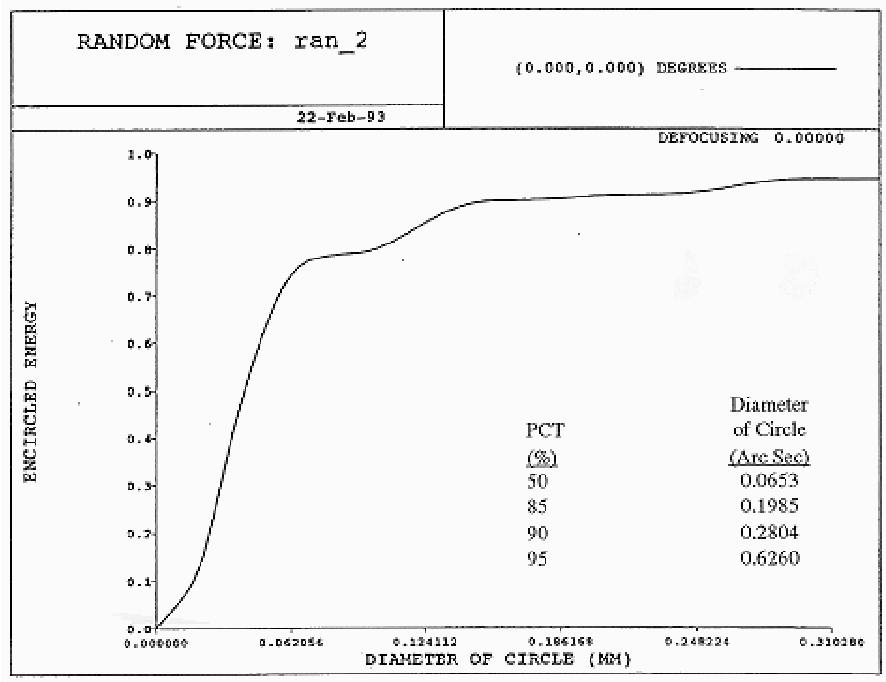


Figure 4. Typical encircled energy distribution.

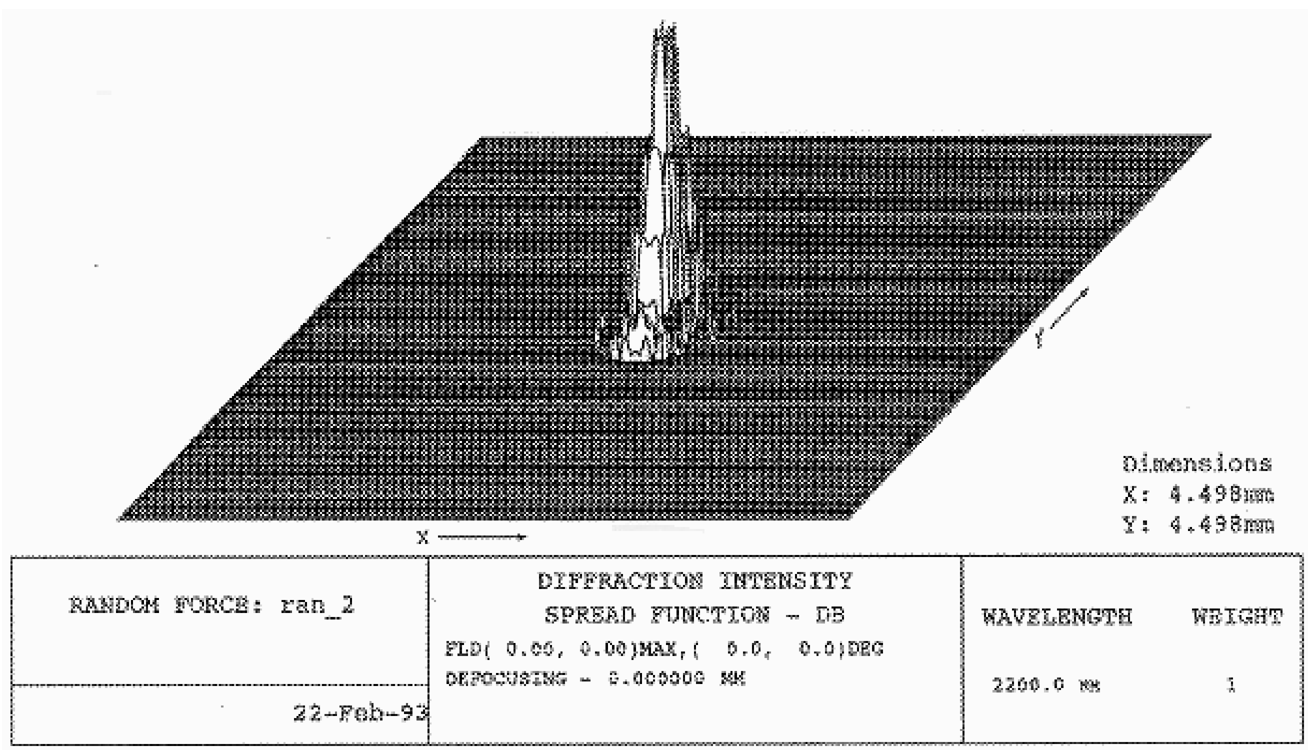
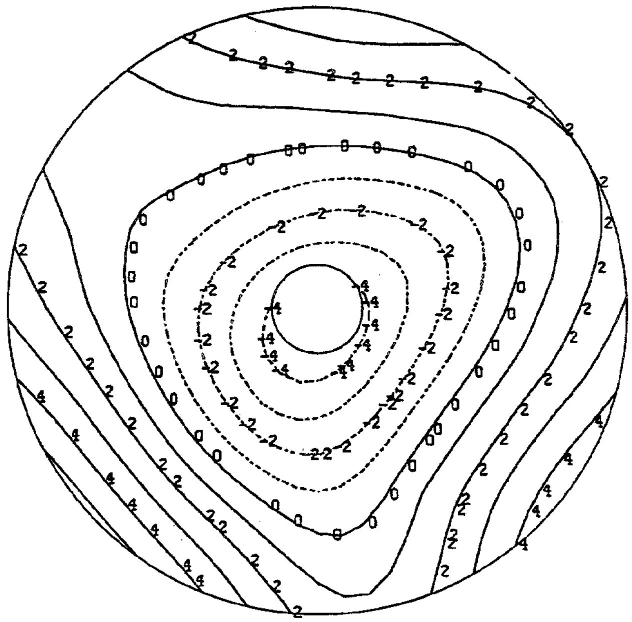
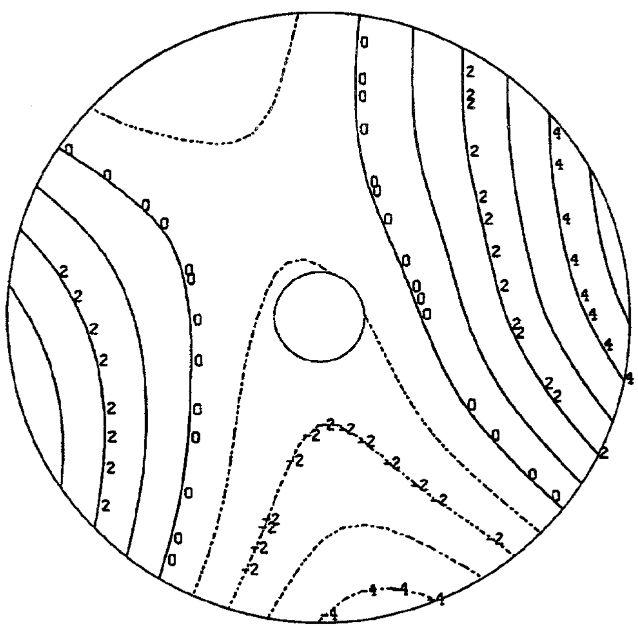


Figure 5. Typical plot of Point Spread Function.



(a)

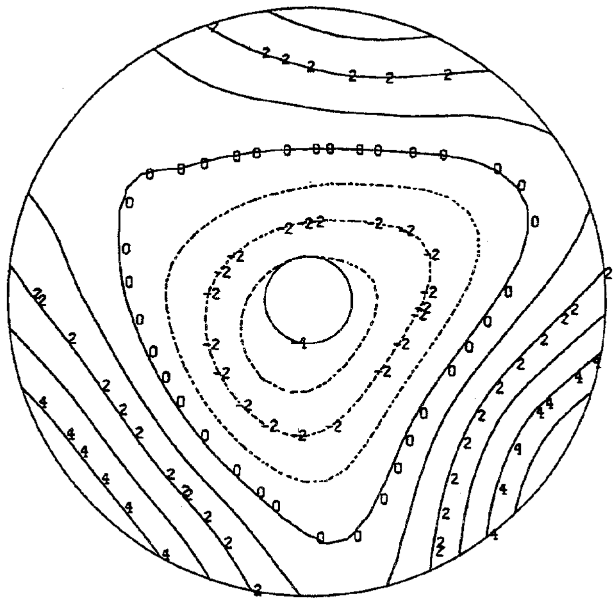


(b)

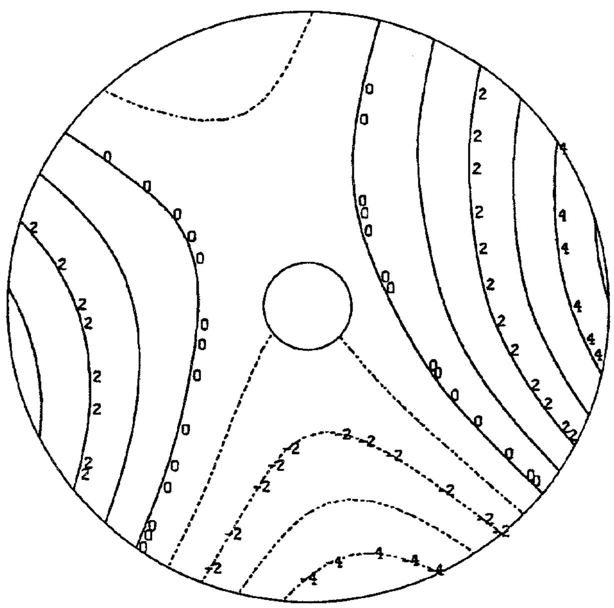
Figure 6. Optical surface figure due to random force case I.

(a) P-V 12.9 NM, RMS 2.9 NM supported by a six-zone support system

(b) P-V 42.7 NM, RMS 8.5 NM supported by a three-zone support system



(a)

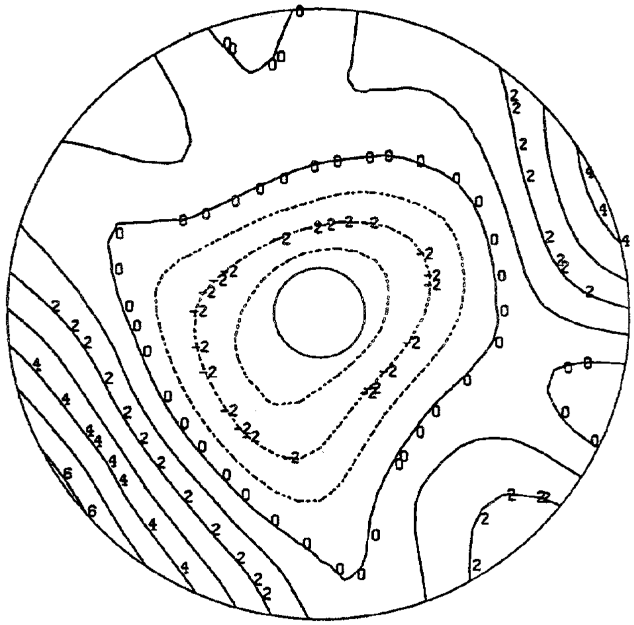


(b)

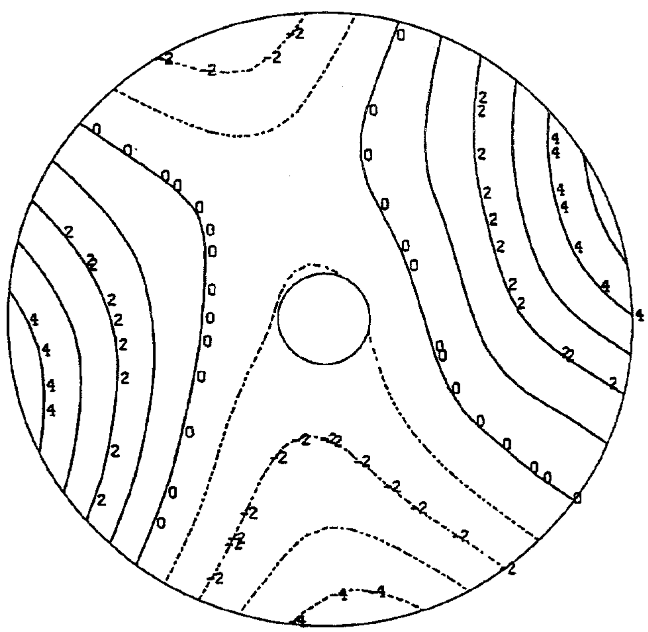
F**igure 7**. Optical surface figure due to random force case II.

(a) P-V = 14.6 NM, RMS = 3.0 NM supported by a six-zone support system

(b) P-V = 61.9 NM, RMS = 11.9 NM supported by a three-zone support system



(a)

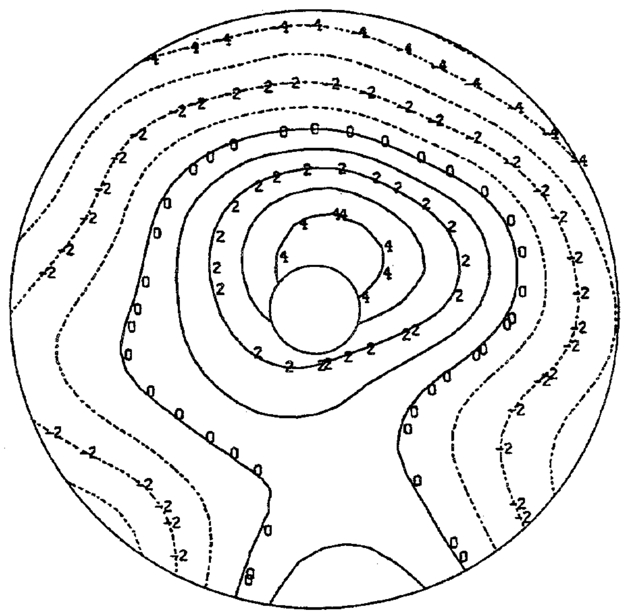


(b)

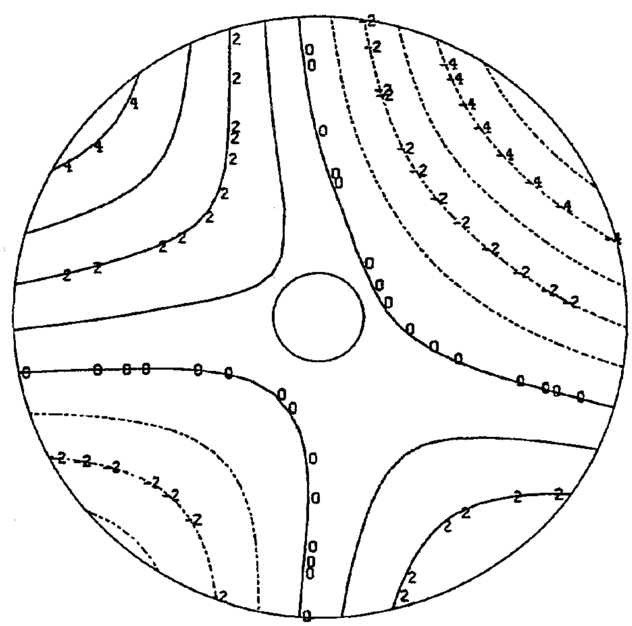
Figure 8. Optical surface figure due to random force case III.

(a) P-V = 5.9 NM, RMS = 1.2 NM supported by a six-zone support system

(b) P-V = 19.0 NM, RMS = 3.8 NM supported by a three-zone support system



(a)

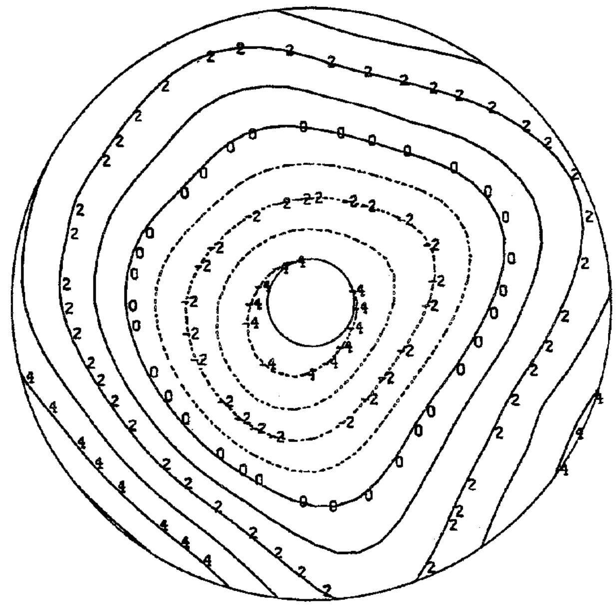


(b)

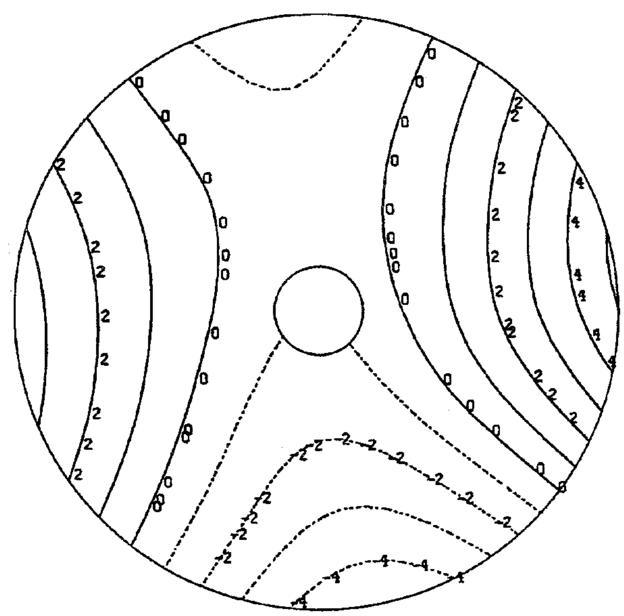
Figure 9. Optical stuface figure due to random force case IV.

(a) P-V = 9.2 NM, RMS = 2.0 NM supported by a six-zone support system

(b) P-V = 71.6 NM, RMS = 14.2 NM supported by a three-zone support system



(a)

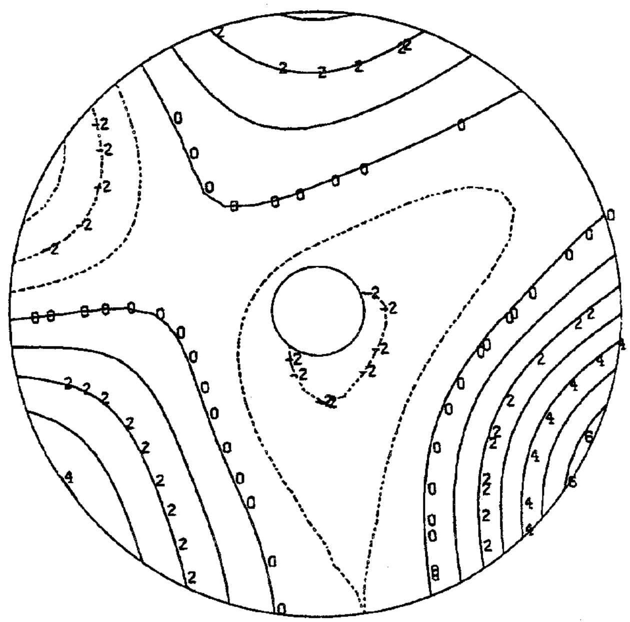


(b)

Figure 10. Optical surface figure due to random force case V.

(a) P-V = 11.8 NM, RMS = 2.7 NM supported by a six-zone support system

(b) P-V = 61.3 NM, RMS = 11.8 NM supported by a three-zone support system



(a)

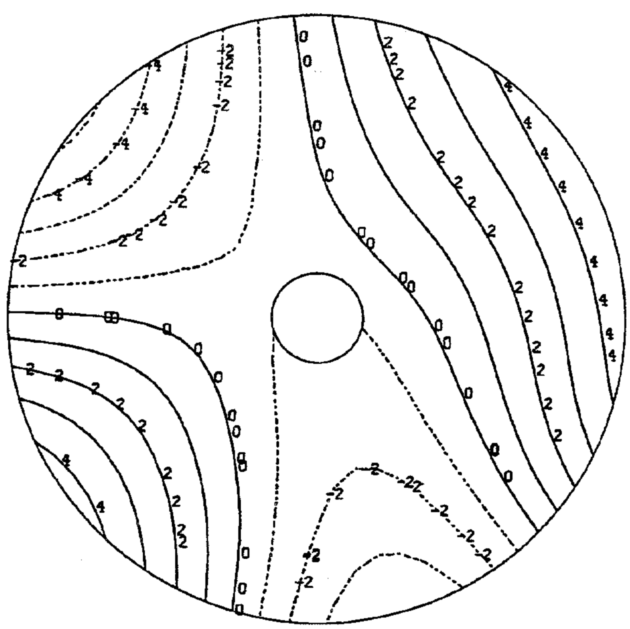


Figure 11. Optical surface figure due to random force case VI.

(a) P-V = 24.7 NM, RMS = 4.3 NM supported by a six-zone support system

(b) P-V = 45.7 NM, RMS = 10.0 NM supported by a three-zone support system

TABLE 1

A normalized random force set with three sigma amplitude over 120 samples.

-0.3953	-0.0329	-0.1782	0.0175	0.0116	0.0050
-0.0122	-0.1314	-0.0063	0.0348	-0.1039	-0.2381
-0.2293	0.2844	-0.2967	-0.1197	-0.0884	0.2731
0.4015	0.1066	0.3417	-0.0899	-0.1971	-0.4184
0.0715	0.1479	0.0316	-0.0234	-0.2619	1.0000
-0.3426	-0.2894	0.3327	-0.1371	0.7332	-0.1032
0.2114	-0.1793	0.2456	0.5604	-0.2793	0.1943
-0.4786	-0.1897	-0.0543	-0.0718	0.2330	0.0170
0.3354	-0.2503	0.1711	0.1928	0.2173	-0.0130
0.3687	-0.0373	-0.0460	-0.1045	0.2346	0.3712
-0.4192	-0.7663	0.0684	0.1239	-0.3079	-0.3685
-0.1624	-0.4552	-0.0511	-0.1178	-0.0076	-0.0712
0.0036	0.0763	0.4126	-0.4996	-0.1898	-0.0343
-0.0362	0.0330	-0.1026	-0.3188	0.0111	0.5313
0.3584	-0.0792	0.0828	-0.3346	0.4756	-0.0021
-0.0764	0.3069	-0.0964	0.1430	0.0735	0.1574
-0.3795	-0.0159	0.3561	-0.2837	-0.0525	-0.4460
0.1204	0.2089	0.2053	0.0275	-0.0099	-0.1480
0.3284	0.0703	-0.0770	-0.2086	0.5833	-0.3038
0.3891	-0.8003	0.1141	0.0835	0.1730	-0.0422

summary of Random force set:

max	min	P-V	rifts	avg
1.0000	-0.8003	1.8003	0.2812	0.0000

total number of data sampling points = 120

TABLE 2

Surface distortion due to random force effors for the primary on six-zone and three-zone whiffle-tree support systems. (maximum force error at three sigma amplitude = 0.5 Newtons).

Random Force Set	P _ V (NM) 6 zone	P _ V (NM) 3 zone	RMS (NM) 6 zone	RMS (NM) 3 zone	RMS (NM) ratio
I	12.9	42.7	2.9	8.5	2.9
II	14.6	61.9	3.0	11.9	4.0
III	5.9	19.0	1.2	3.8	3.2
IV	9.2	71.6	2.0	14.2	7.1
V	11.8	61.3	2.7	11.8	4.4
VI	24.7	45.7	4.3	10.0	2.3