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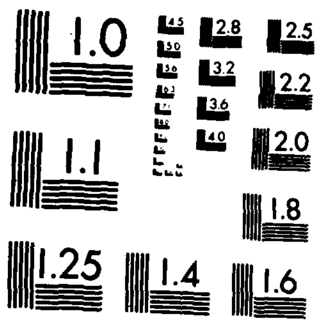

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TECHNICAL REPORT RL-82-3

RANGE DETERMINATION AND EVALUATION OF LASER SPECKLE INTERFEROMETRY

Terry L. Vandiver
Sandra W. Cameron
Robert N. Evans
Tom W. Yost
Structures Directorate
US Army Missile Laboratory

FEBRUARY 1982

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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The objective of the effort was to determine the range of laser speckle interferometry. An XP-250 Epoxy E-glass specimen was illuminated by an optical process utilizing an argon laser as a coherent light source. The displacement was achieved by angular rotation about a reference point. Geometric and trigonometric functions were used to analytically determine magnitudes and directions of displacement. The optical setups and a description of the computer system to analyze the interferogram is also presented. An analytical-experimental

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comparison of displacements and rotation angle is also included. A statistical analysis including standard deviation and coefficient of variation was utilized.

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LIST OF SYMBOLS

Symbols	Definition
D	Spacing between Fringes
L	Experimental Displacement
T	Length of Axis of Rotation
U_H	Horizontal Displacement Component
U_V	Vertical Displacement Component
U_θ	Experimental Inplane Displacement
X	Horizontal Coordinate
Y	Vertical Coordinate
f	Distance from Interferogram to Analyzer Screen
m	Fringe Order
s	Film Scale Factor
α	Rotation Angle
β	Angle Opposite α
θ	Fringe Angle of Orientation
λ	Wavelength of Laser Light

I. INTRODUCTION

The primary objective of this research task was to determine the displacement range of laser speckle interferometry. Interferometry utilizes light interference phenomena for non-destructive, sensitive determinations of in-plane displacements. The displacement data can be differentiated to obtain strains which can in turn be correlated with shearing stresses [1].

The laboratory setup for preparation of the interferograms utilized an argon laser as a coherent light source to illuminate the specimen. The interferograms were prepared by double exposure photography techniques. Analysis of the interferograms employed a computer aided scanning system that was developed primarily for evaluation of speckle interferometric data.

Conventional techniques of measuring surface strain and displacement data utilize strain gages, dial gages and various other electromechanical sensing devices. Although such methods are extremely accurate, information is limited to very small regions [2]. These techniques are ideal for homogeneous materials; however, nonconventional applications are required for anisotropic nonhomogeneous materials such as composites. Laser speckle interferometric data provides the investigator with non-contact full-field information over an entire region of interest.

II. OPTICAL TEST SETUP AND PROCEDURE

The experimental test arrangement used to determine the interferogram range is shown in Figures 1 and 2. A Spectra Physics argon laser adjusted at 0.50 watts was used as a coherent light source to illuminate the specimen. A double exposure photography technique using AGFA - GEVAERT Holotest 10E-56 glass film plates was used to prepare the interferograms. The interferograms were developed with conventional photography techniques.

Figure 3 shows the specimen setup used in speckle range determination. The translation stage was positioned on a vibration free table by means of a magnetic base. A lens positioner assembly was mounted on the translation table with 2 polished steel rods 1.27 cm in diameter. A mounting block extending from the lens positioner contained 2 small steel rods on which the rotation stage was mounted. The specimen was attached to a small block that was bolted on the rotation table.

Three people were involved in preparing a complete set of interferograms. One person rotated the specimen between each exposure by means of a micrometer control. Another person on the optics side of the setup shielded the lens between each exposure so as not to destroy the interferograms. A third person monitored the remote shutter control, timer, and lights. The complete interferogram preparation process was done in the dark. Any leakage of white light on the film plate would destroy the interferogram.

A double exposure photography technique was utilized to make the interferograms. The first exposure was made with the specimen rotated 0.05° from a center reference point. Next the camera lens is covered to prevent overexposure of the film plates; the specimen is rotated 0.10° and a second exposure is taken. The time required for each exposure is four seconds.

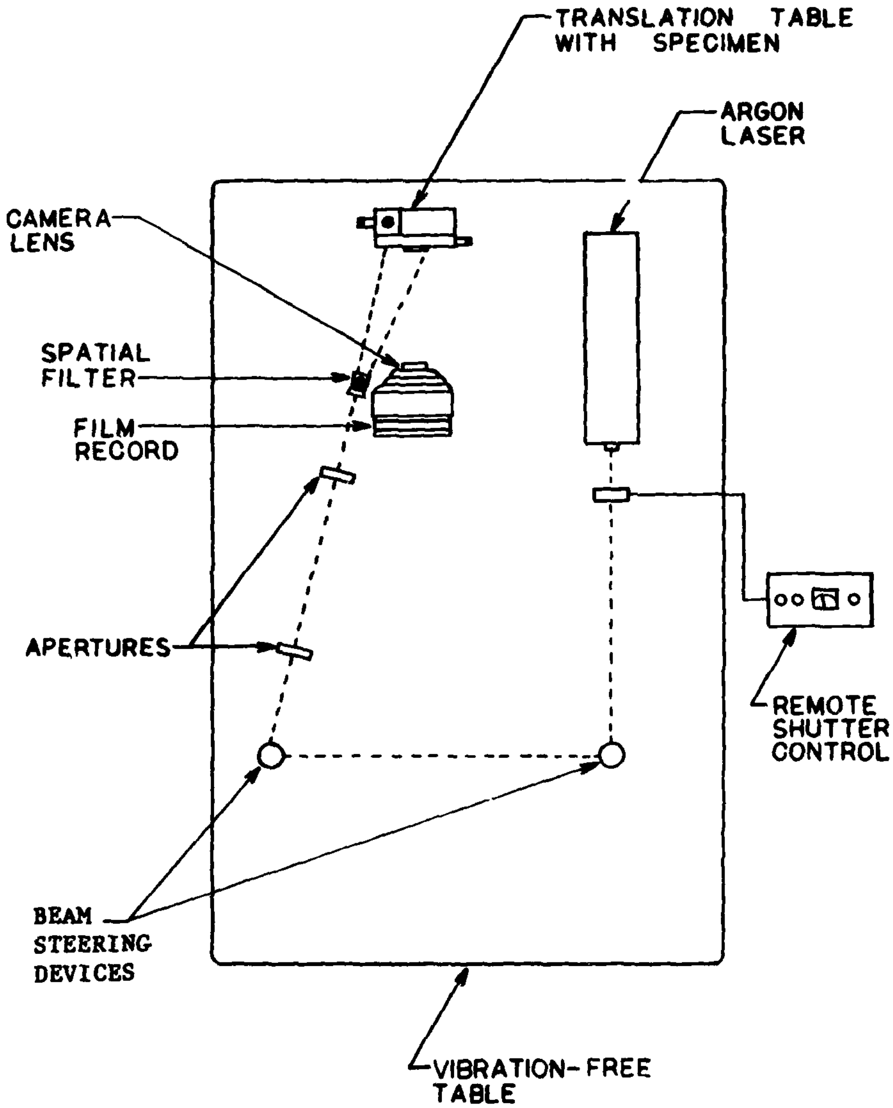

Figure 1. Experimental test setup (sketch).

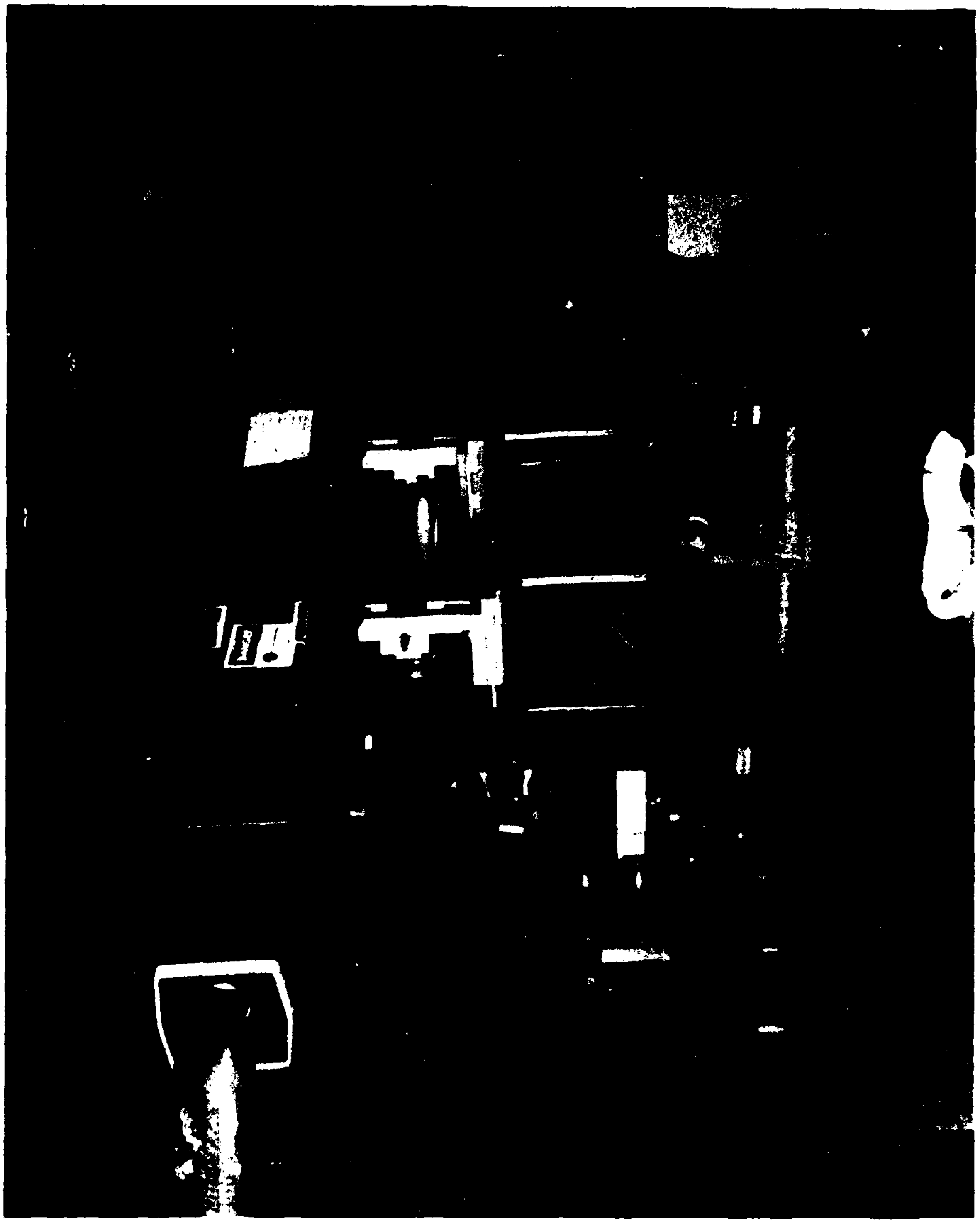

Figure 2. Experimental test setup (photo).

III. DATA ANALYSIS

A. Computer Scan System

The experimental displacement data was collected by the interferometric analysis system shown in Figure 4. This system utilizes an optical setup and computer hardware which was developed primarily for applications in speckle interferometric data analysis. The interferograms were placed in a viewing window of the x-y translation table and reilluminated by a HeNe laser beam. The illumination produces a fringe pattern on a diffuser screen which included a 360° protractor used to measure the displacement angle of the fringes. The displacement of the region illuminated is inversely proportional to the spacing between fringes. The direction of displacement is along an axis orthogonal to the fringe orientation. A typical fringe pattern is shown in Figure 5.

A very small region of the interferogram is illuminated and, therefore, the data yields the displacement at a point. In order to obtain a complete description of the surface, the interferograms were scanned by the x-y translation table using the coordinate system shown in Figure 6. The translation stage is capable of 0.0025 cm incremental movements with a 0.00025 cm repositioning accuracy. The location of the desired point on the interferogram was controlled by translation stage stepping motors which were in turn controlled by the computer. The computer program used to control the scan pattern and calculate the displacements appears in the Appendix.

B. Displacement Determination

1. *Analytical Considerations*

A sketch of the geometry utilized to analytically determine the displacement is presented in Figure 7.

Equidistant rotation of length T about a center point produced an isosceles triangle which could be analyzed with the law of sines formulation as given by Leithold [3]. The angle of rotation was determined by turning the micrometer 7.9 microns per 0.10° while making the interferograms. With two sides and an angle known, the displacement can now be determined.

$$\frac{L}{\text{SIN}\ \alpha} = \frac{T}{\text{SIN}\ \beta} \qquad (1)$$

so

$$L = \frac{\text{SIN}\ \alpha}{\text{SIN}\ \beta}\ T \qquad (2)$$

where

L = Displacement
α = Angle of Rotation
$\beta = 180^{\circ} - (90^{\circ} + \frac{\alpha}{2})$
T = Length of axis of rotation

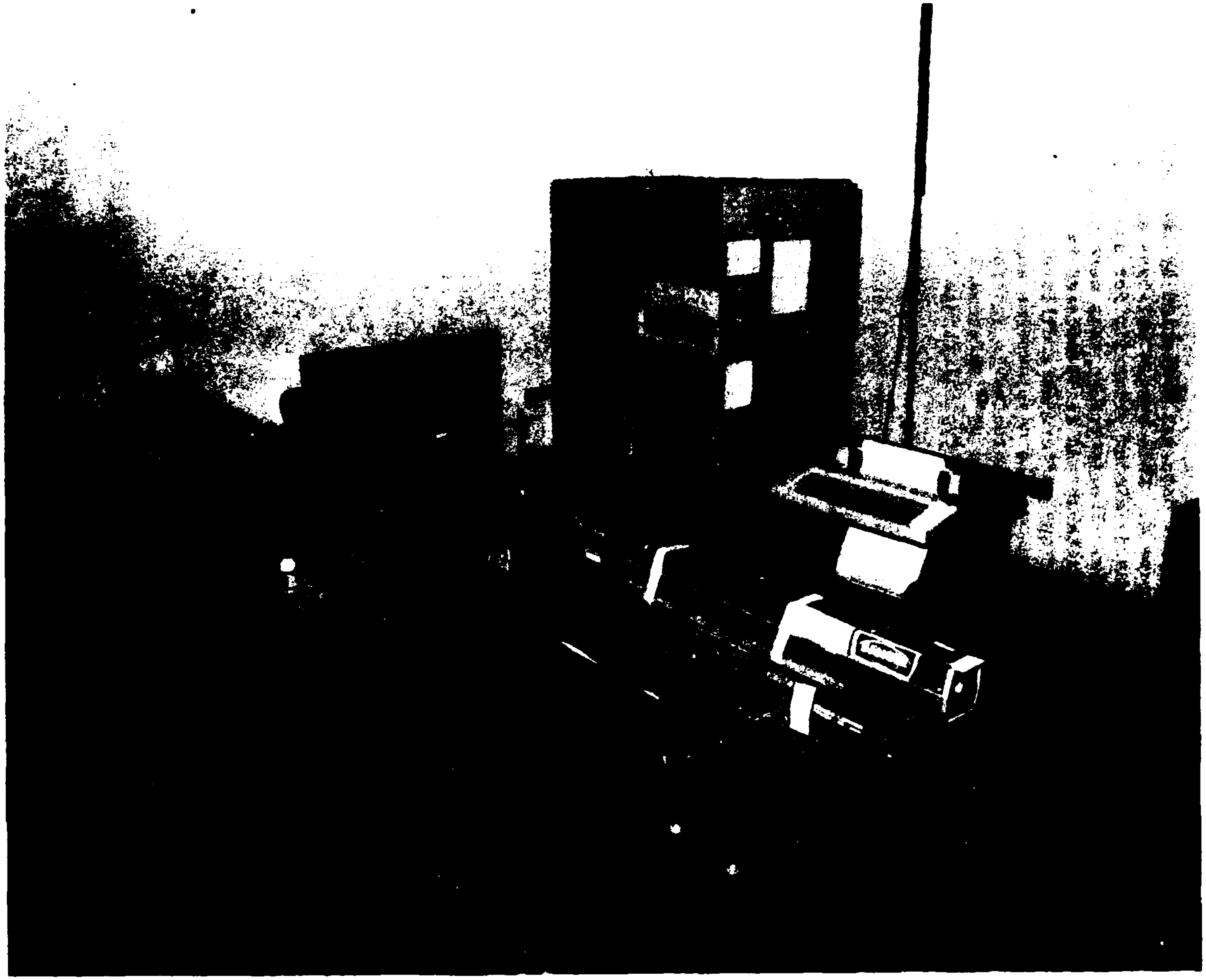

Figure 4. Computer analysis system.

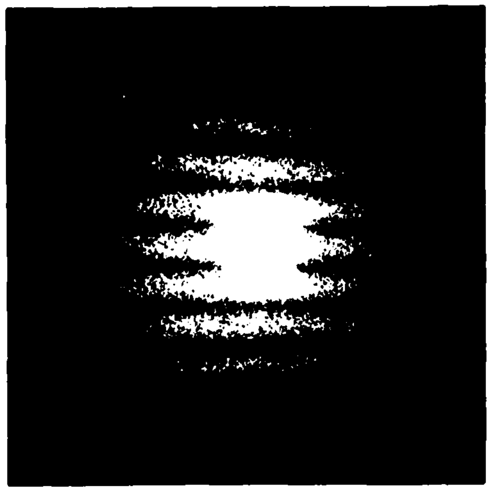

Figure 5. Typical fringe pattern.

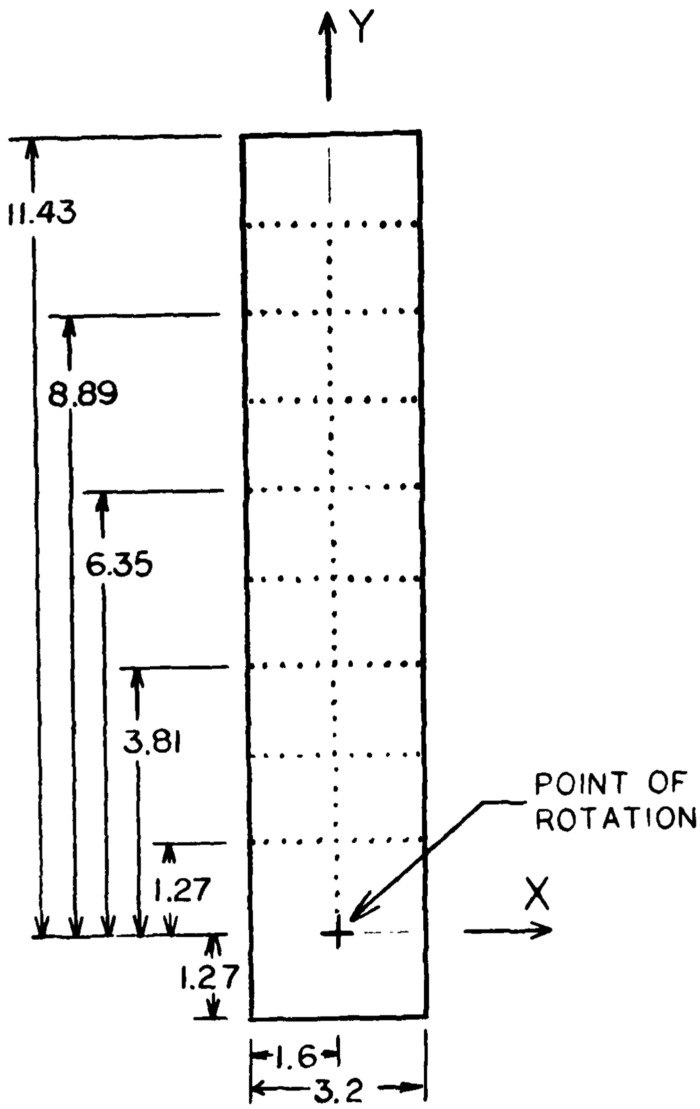

Figure 6. Scan coordinate system (dimensions in cm).

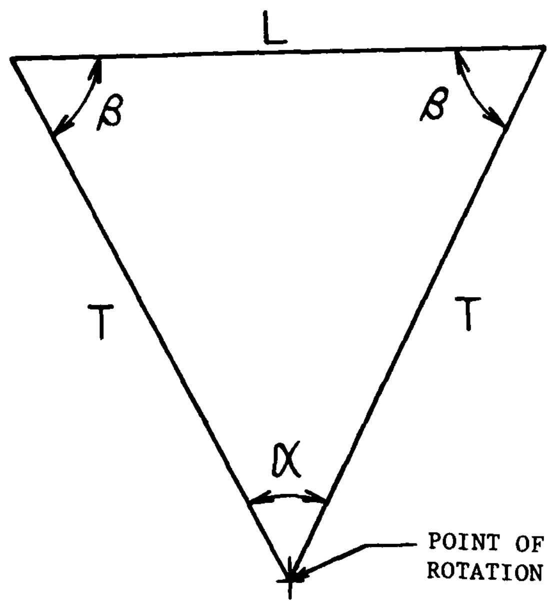

Figure 7. Geometrical angular rotation.

2. Experimental Considerations

A computer aided scanning system was utilized to analyze the interferograms experimentally. The interferograms were placed on an x-y translation table controlled by a computer program. The scanning setup used to project halos of the interferograms onto a diffuser screen is shown in Figure 8. The computer controlled translation table housing the interferogram was moved in a raster pattern through a stationary laser beam. Fringe spacing and the angle of orientation at each data point were entered into the computer which in turn calculated the displacements from:

$$U_\theta = \frac{m\lambda f s}{D} \quad (3)$$

where

U_θ	=	Experimental inplane displacement
D	=	Spacing between fringes
m	=	Fringe order
f	=	Distance from interferogram to analyzer screen
s	=	Film scale factor
λ	=	Wavelength of laser light

The complete derivation of Equation (3) appears in Mullinix [4]. The vertical and horizontal components of displacements were also determined from:

$$U_V = \frac{m\lambda f s}{D} \cos\theta \quad (4)$$

$$U_H = \frac{m\lambda f s}{D} \sin\theta \quad (5)$$

The wavelength of the HeNe laser used in the interferometric analysis is 6328Å. The film scale factor is found by dividing the true length of the specimen by the image length on the interferogram. The computer programs utilized in the analysis appear in the Appendix.

IV. RESULTS

The primary purpose of this research project was to determine the maximum and minimum effective range of laser speckle interferometry. The maximum range determined by the method described was 35149.0 μcm with an error of 1.62% from the analytical value. The minimum range was found to be 6.85.8 μcm with an error of 3.03%. The average error, or total coefficient of variation for analytical and experimental values of all points scanned (Tables 1 through 3) was 5.96%. This error could be attributed to discrepancies in angular rotation of the specimen, inaccurate measurements taken for computer scan program, and reader error.

Horizontal scan plots (Figures 9 through 12) indicate that there is a direct relationship between angle of rotation and amount of displacement. Figure 9 shows that, as the angle of rotation increases from 0.10° to 0.20°

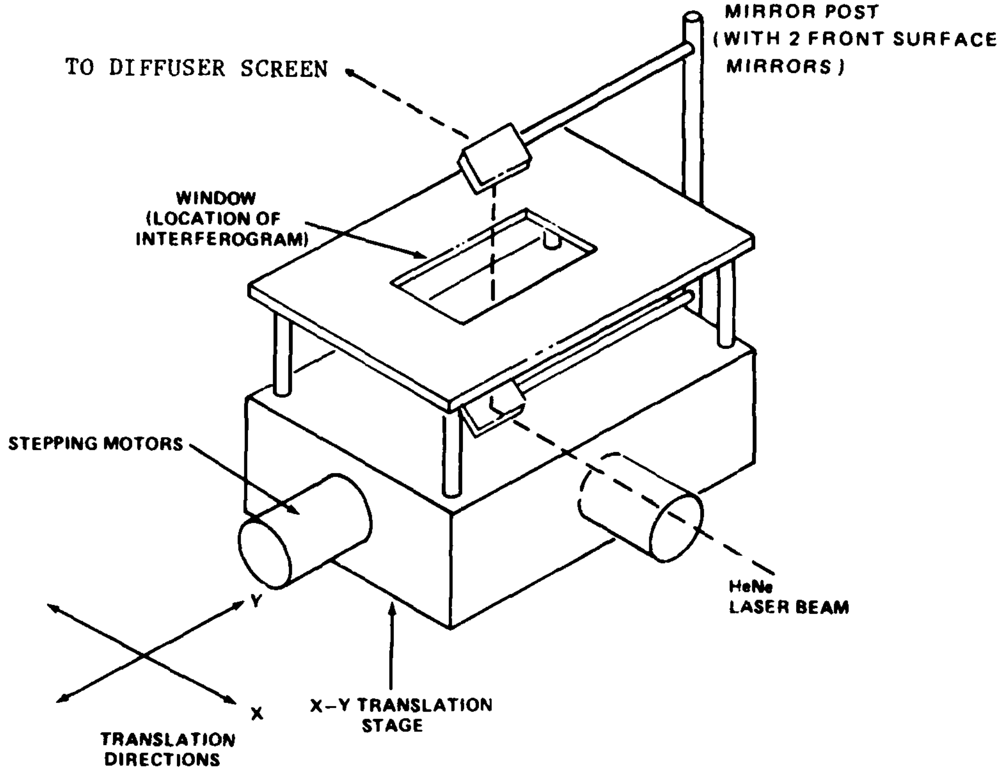

Figure 8. X-Y translation stage.

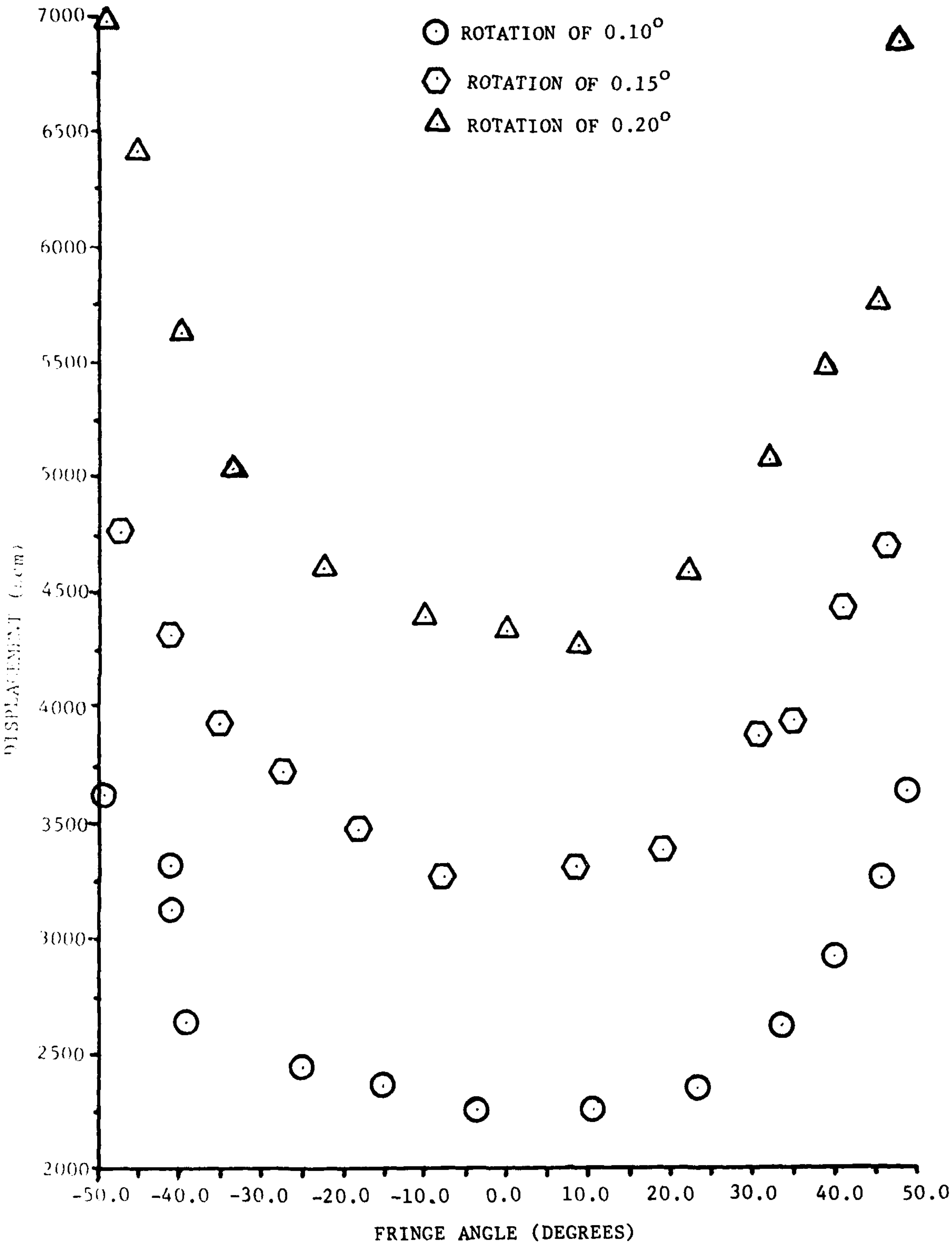

Figure 9. Fringe angle vs. displacement horz. scan (1.27 cm from x-axis).

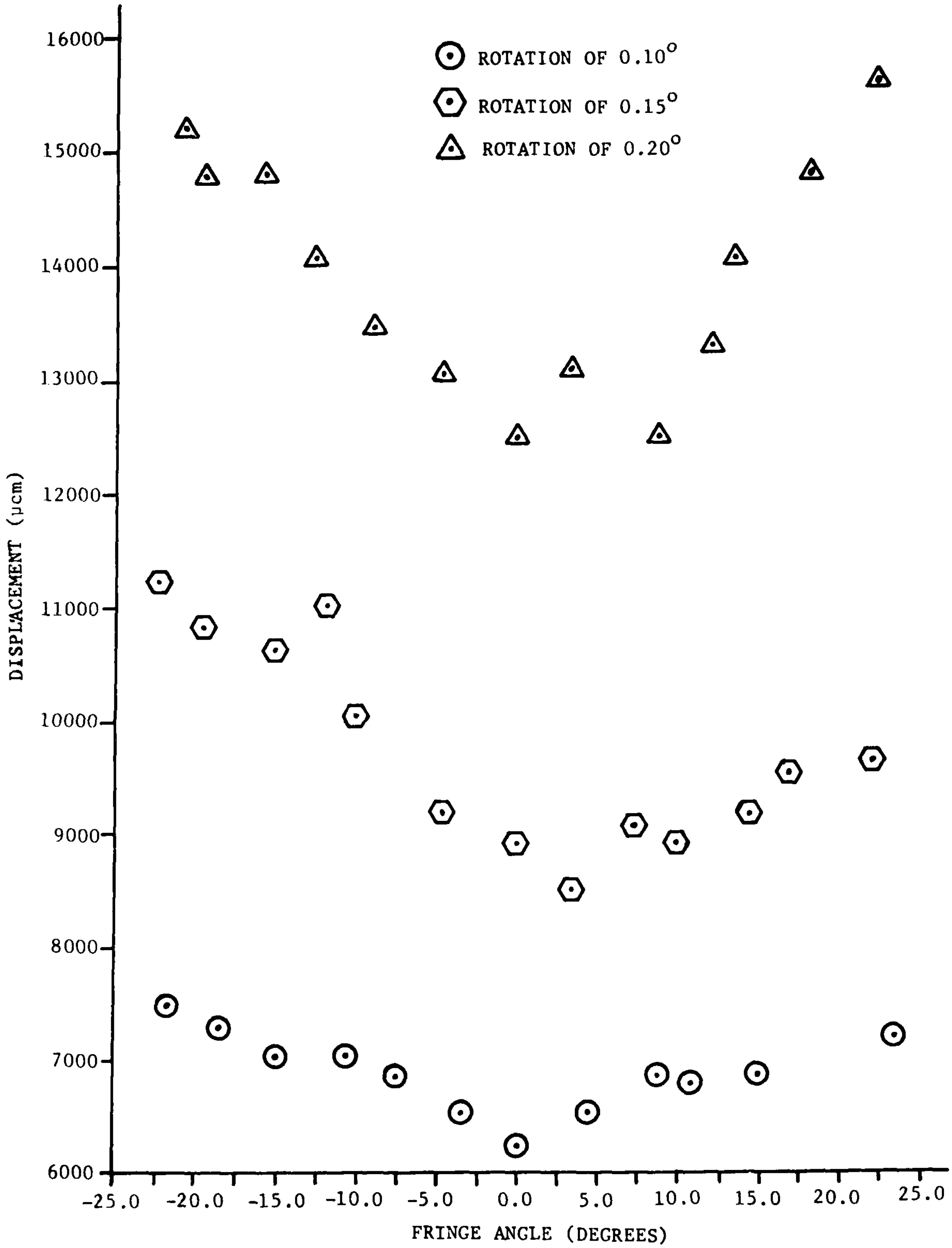

Figure 10. Fringe angle vs. displacement horiz. scan (3.81 cm from x-axis).

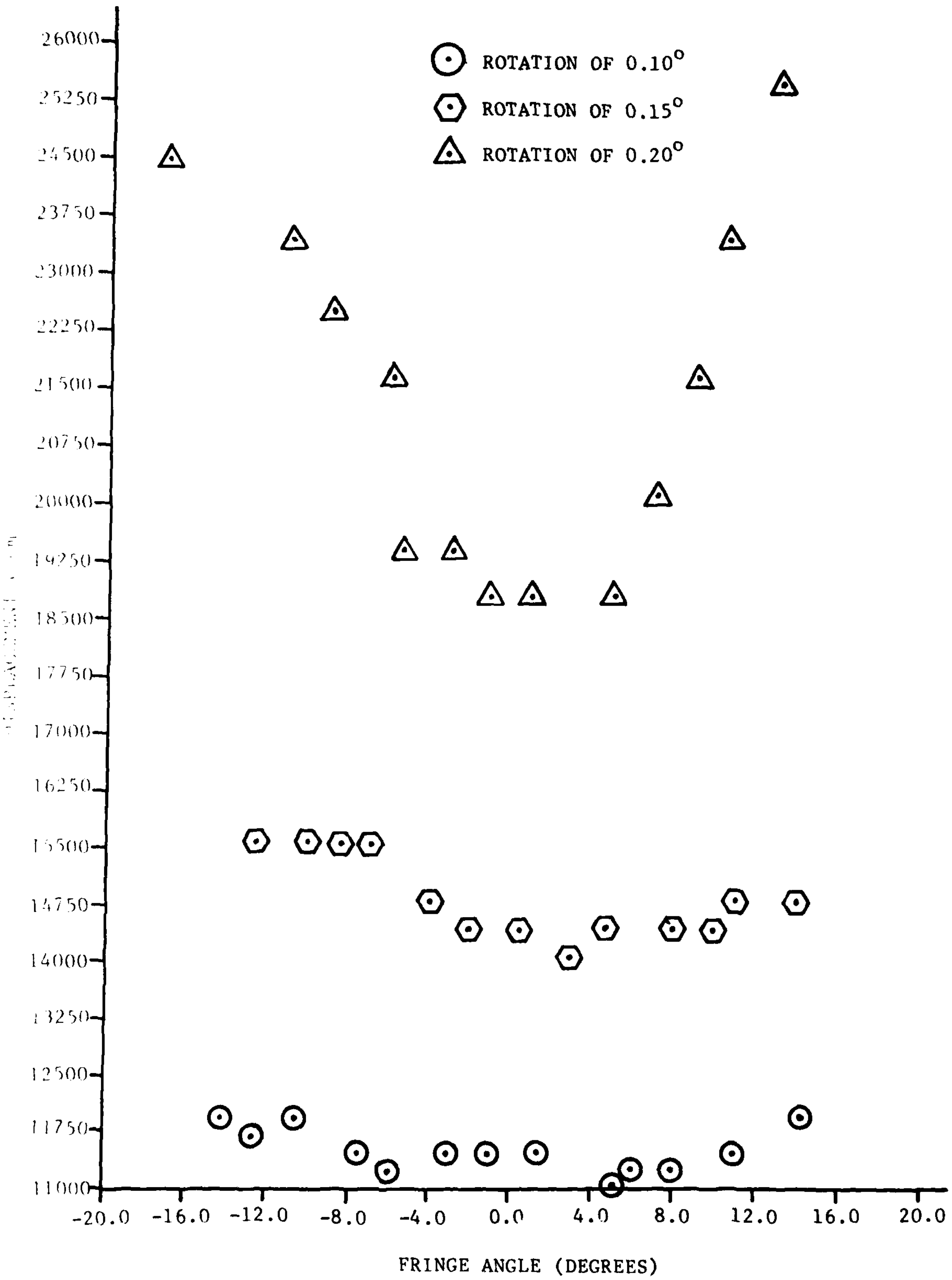

Figure 11 . Fringe angle vs. displacement horz. scan (6.35 cm from x-axis).

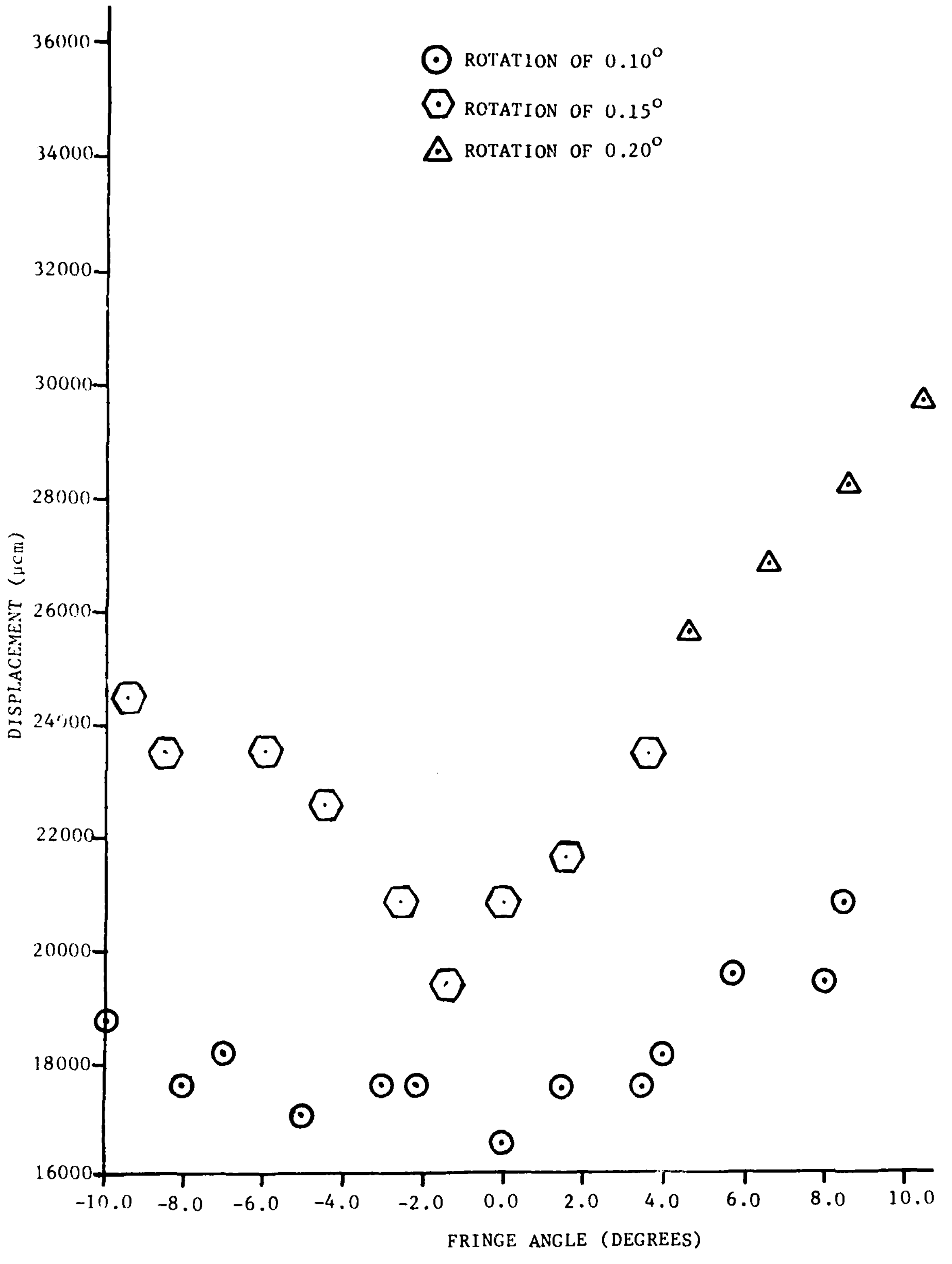

Figure 12. Fringe angle vs. displacement horiz. scan (8.89 cm from x-axis).

TABLE 1. VERTICAL SCAN DATA SRD-39 (0.10^{o} ROTATION)

Y CENTER SCAN (cm)	U_θ - μcm			COEFFICIENT OF VARIATION
	ANALYTICAL	EXPERIMENTAL	DEVIATION	
0.000	-	-	-	-
0.254	-	-	-	-
0.508	887	686	201	22.68
0.762	1330	1308	22	1.66
1.016	1773	1731	43	2.40
1.270	2217	2295	79	3.43
1.524	2660	2678	18	0.67
1.778	3103	3308	205	6.20
2.032	3546	3800	254	6.67
2.286	3990	4105	115	2.80
2.540	4433	4535	102	2.26
2.794	4876	5160	284	5.50
3.048	5320	5624	304	5.40
3.302	5763	5798	35	0.60
3.556	6206	6539	333	5.09
[illegible].810	6650	6858	209	3.04
4.064	7093	7210	117	1.62
4.318	7536	7600	64	0.84
4.572	7979	7811	169	2.12
4.826	8423	8270	153	1.81
5.080	8866	9071	205	2.25
5.334	9309	9532	223	2.33
5.588	9753	10415	662	6.35
5.842	10196	10815	619	5.72
6.096	10639	11027	388	3.52
6.350	11083	11637	555	4.76
6.604	11526	11966	440	3.67
6.858	11969	13390	1421	10.61
7.112	12413	13390	978	7.30
7.366	12856	14060	1204	8.56
7.620	13299	14800	1500	10.14
7.874	13742	14420	678	4.70
8.128	14186	15200	1014	6.67
8.382	14629	15622	993	6.35
8.636	15072	15622	549	3.52
8.890	15516	16541	1025	6.20
9.144	15959	17042	1083	6.35
9.398	16402	17575	1172	6.67
9.652	16846	18746	1901	10.14
9.906	17289	18746	1457	7.77
10.16	-	-	-	-

TABLE 2. VERTICAL SCAN DATA SRD-40 (0.15^{o} ROTATION)

Y CENTER SCAN (cm)	U_θ - μcm			COEFFICIENT OF VARIATION
	ANALYTICAL	EXPERIMENTAL	DEVIATION	
0.000	-	-	-	-
0.254	665	686	20.8	3.03
0.508	1330	1339	9	0.69
0.762	1995	2045	50	2.45
1.016	2660	2616	44	1.66
1.270	3327	3308	19	0.57
1.524	3990	3800	190	4.76
1.778	4655	4610	45	0.97
2.032	5320	5021	299	5.61
2.286	5985	5514	471	7.87
2.540	6650	6113	537	8.07
2.794	7315	6695	620	8.47
3.048	7980	7921	59	0.74
3.302	8645	8034	611	7.06
3.556	9310	8394	916	9.84
3.810	9975	9071	904	9.06
4.064	10640	9696	943	8.87
4.318	11305	10815	498	4.33
4.572	11970	11248	722	6.03
4.826	12635	11248	1387	10.98
5.080	13299	11966	1334	10.03
5.334	13964	12497	1467	10.51
5.588	14629	11966	2664	18.21
5.842	15294	13079	2216	14.49
6.096	15959	13390	2569	16.10
6.350	16624	14060	2565	15.43
6.604	17289	14060	3230	18.68
6.858	17954	14800	3155	17.57
7.112	18619	15200	3420	18.37
7.366	19284	16068	3216	16.68
7.620	19949	17042	2907	14.57
7.874	20614	18141	2473	12.00
8.128	21279	18746	2533	11.90
8.382	21944	20085	1859	8.47
8.636	22609	20085	2524	11.16
8.890	23274	21630	1644	7.06
9.144	23939	22495	1444	6.03
9.398	24604	24452	152	0.62
9.652	25269	24452	817	3.23
9.906	25934	25563	371	1.43
10.16	-	-	-	-

TABLE 3. VERTICAL SCAN DATA SRD-41 (0.20° ROTATION)

Y CENTER SCAN (cm)	U_{θ} - μcm			COEFFICIENT OF VARIATION
	ANALYTICAL	EXPERIMENTAL	DEVIATION	
0.000	-	-	-	-
0.254	887	781	106	11.91
0.508	1773	1814	41	5.73
0.762	2660	2744	84	3.05
1.016	3547	3559	13	0.36
1.270	4433	4228	205	4.62
1.524	5320	4890	430	8.07
1.778	6207	5739	468	7.54
2.032	7093	7030	63	0.89
2.286	7980	7600	380	4.76
2.540	8866	8270	596	6.72
2.794	9753	9373	380	3.89
3.048	10640	10815	176	1.62
3.302	11525	11248	278	2.41
3.556	12413	11477	936	7.54
3.810	13299	12497	802	6.03
4.064	14186	13390	796	5.61
4.318	15073	14800	273	1.81
4.572	15959	16068	109	0.68
4.826	16846	18141	1296	7.14
5.080	17733	18746	1014	5.41
5.334	18619	19393	773	3.99
5.588	19506	18746	760	3.89
5.842	20392	20085	307	1.51
6.096	21279	21630	351	1.62
6.350	22166	24452	2286	9.35
6.604	23052	23433	380	1.62
6.858	23939	24452	513	2.10
7.112	24826	26780	1955	7.30
7.366	25712	26780	1068	3.99
7.620	26599	28119	1520	5.41
7.874	27485	28119	634	2.25
8.128	28372	29599	1227	4.15
8.382	29259	29599	340	1.15
8.636	30145	31244	1098	3.52
8.890	31032	33082	2050	6.20
9.144	31919	33082	1162	3.51
9.398	32805	33082	276	0.84
9.652	33692	33082	610	1.84
9.906	34579	35149	571	1.62
10.16	-	-	-	-

at a fixed Y = 1.27 cm value, there is a proportional increase in the displacements. In addition, it is seen that the displacements are symmetrical about the center line of the specimen, which is located where the fringe angle is zero. Data for these plots are displayed in Tables 4 through 9.

V. SUMMARY AND CONCLUSIONS

The laser speckle interferometric range was determined by applying an optical process that utilizes a coherent laser light source for precise determination of linear inplane displacements. The analysis of the interferograms was accomplished by a computer aided scanning system designed primarily for evaluating interferometric data. This nondestructive, highly sensitive method of analysis is extremely accurate and provides the investigator with full-field displacement data. A full-field reconstructed optical Fourier transform image of the displacement region can also be produced by this technique.

For this research task, a composite test specimen was scanned both vertically and horizontally at four specified regions. The maximum and minimum displacement was determined to be 35149.0μcm and 685.8μcm, respectively. Horizontal scan evaluation indicated that the rotational angle and the amount of displacement increase proportionally. This research exercise demonstrates the capability to capture deformation under load of rotating objects such as helicopter blades and high speed turbine vanes. A pulsed high energy coherent light source and high resolution multiple exposure film would be required to capture the interferometric data. The interferogram could be investigated woth qualitatively for anomalies in the structures as well as quantitatively to provide deformation under load profiles for engineering design applications.

Attempts have been made by Swinson [5] to increase the effective range of laser speckle interferometry coupled with accoustical interferometry through sandwiching techniques. The technique introduces a rigid body shift into the deformed state of a test object to increase the number of readable fringes; after which, the rigid body effects are subtracted out of the analysis. There is a definite need for rapid advancement in the state-of-the-art of laser speckle interferometry to include the most advanced methods of computer analysis and optical image processing.

TABLE 4. HORIZONTAL SCAN DATA SRD-39 (0.10^c ROTATION)

Y / X (cm)	1.27 cm				3.81 cm			
	U (μcm)	U_H (μcm)	U_V (μcm)	Θ	U (μcm)	U_H (μcm)	U_V (μcm)	Θ
1.524	3628	2381	2738	49.0	7210	6612	2875	23.5
1.270	3251	2338	2258	44.0	6858	6504	2176	18.5
1.016	2884	2241	1815	39.0	6464	6244	1673	15.0
0.762	2616	2194	1425	33.0	6776	6651	1293	11.0
0.508	2343	2141	953	24.0	6858	6807	836	7.0
0.254	2249	2208	429	11.0	6539	6524	456	4.0
0.000	2249	2246	- 118	- 3.0	6249	6249	00	0.0
-0.254	2363	2293	- 572	-14.0	6539	6527	- 399	- 3.5
-0.508	2445	2216	-1033	-25.0	6858	6800	- 895	- 7.5
-0.762	2633	2062	-1670	-39.0	7030	6901	-1341	-11.0
-1.016	3125	2358	-2050	-41.0	7030	6790	-1819	-15.0
-1.270	3328	2394	-2312	-44.0	7304	6926	-2318	-18.0
-1.524	3628	2385	-2734	-48.9	7498	6953	-2809	-22.0

TABLE 5. HORIZONTAL SCAN DATA SRD-39 (0.10° ROTATION)

Y / X (cm)	6.35 cm				8.89 cm			
	U (μcm)	U_H (μcm)	U_V (μcm)	Θ	U (μcm)	U_H (μcm)	U_V (μcm)	Θ
1.524	11966	11610	2895	14.0	20829	20600	3079	8.5
1.270	11477	11266	2190	11.0	19393	19204	2699	8.0
1.016	11248	11138	1565	8.0	19508	18660	1797	5.5
0.762	11248	11186	1176	6.0	18141	18097	1265	4.0
0.508	11027	10985	984	5.0	17575	17542	1073	3.5
0.254	11477	11473	301	1.5	17575	17568	460	1.5
0.000	11477	11476	- 200	- 1.0	16541	16541	00	0.0
-0.254	11477	11462	- 601	- 3.0	17575	17564	- 613	- 2.0
-0.508	11248	11186	-1176	- 6.0	17575	17550	- 920	- 3.0
-0.762	11477	11379	-1498	- 7.5	17042	16977	-1485	- 5.0
-1.016	11966	11765	-2181	-10.5	18141	18006	-2211	- 7.0
-1.270	11716	11439	-2536	-12.5	17575	17403	-2446	- 8.0
-1.524	11966	11610	-2895	-14.0	18746	18461	-3255	-10.0

TABLE 6. HORIZONTAL SCAN DATA SRD-40 (0.15^o ROTATION)

X (cm) \ Y	1.27 cm				3.81 cm			
	U (μcm)	U_H (μcm)	U_V (μcm)	Θ	U (μcm)	U_H (μcm)	U_V (μcm)	Θ
1.524	4687	3226	3400	46.5	9696	8990	3632	22.0
1.270	4394	3316	2882	41.0	9532	9115	2787	17.0
1.016	3933	3222	2256	35.0	9219	8928	2308	14.5
0.762	3906	3416	1893	29.0	8927	8777	1627	10.5
0.508	3388	3203	1103	19.0	9071	8993	1184	7.5
0.254	3308	3276	461	8.0	8521	8505	520	3.5
0.000	3270	3234	- 483	- 8.5	8927	8927	00	00.0
-0.254	3471	3302	-1073	-18.0	9219	9191	- 723	- 4.5
-0.508	3724	3319	-1691	-27.0	10043	9890	-1744	-10.0
-0.762	3933	3222	-2256	-35.0	11027	10786	-2293	-12.0
-1.016	4326	3265	-2838	-41.0	10611	10249	-2746	-15.0
-1.270	4766	3250	-3486	-47.0	10815	10195	-3610	-19.5
-1.524	-	-	-	-	11248	10429	-4213	-22.0

TABLE 7. HORIZONTAL SCAN DATA SRD-40 (0.15° ROTATION)

Y / X (cm)	6.35 cm				8.89 cm			
	U (μcm)	U_H (μcm)	U_V (μcm)	Θ	U (μcm)	U_H (μcm)	U_V (μcm)	Θ
1.524	14800	14360	3580	14.0	29599	29104	5394	10.5
1.270	14800	14528	2824	11.0	28119	27810	4156	8.5
1.016	14420	14201	2504	10.0	26780	26608	3032	6.5
0.762	14420	14280	2007	8.0	25563	25484	2006	4.5
0.508	14420	14376	1131	4.5	23433	23389	1431	3.5
0.254	14060	14040	736	3.0	21630	21623	566	1.5
0.000	14420	14420	126	0.5	20829	20829	000	0.0
-0.254	14420	14411	- 503	- 2.0	19393	19386	- 508	- 1.5
-0.508	14800	14764	-1032	- 4.0	20829	20809	- 909	- 2.5
-0.762	15622	15505	-1904	- 7.0	22495	22426	-1765	- 4.5
-1.016	15622	15450	-2309	- 8.5	23433	23304	-2449	- 6.0
-1.270	15622	15385	-2713	-10.0	23433	23175	-3464	- 8.5
-1.524	15622	15251	-3381	-12.5	24452	24116	-4036	- 9.5

TABLE 8. HORIZONTAL SCAN DATA SRD-41 (0.20^{o} ROTATION)

Y / X (cm)	1.27 cm				3.81 cm			
	U (μcm)	U_H (μcm)	U_V (μcm)	Θ	U (μcm)	U_H (μcm)	U_V (μcm)	Θ
1.524	6858	4545	5137	48.5	15622	14433	5978	22.5
1.270	5739	4022	4093	45.5	14800	14035	4696	18.5
1.016	5460	4243	3436	39.0	14060	13671	3282	13.5
0.762	5067	4297	2685	32.0	13390	13098	2784	12.0
0.508	4572	4239	1713	22.0	12497	12360	1847	8.5
0.254	4261	4208	667	9.0	13079	13054	798	3.5
0.000	4326	4326	000	0.0	12497	12497	000	0.0
-0.254	4394	4327	- 763	-10.0	13079	13038	-1026	- 4.5
-0.508	4610	4259	-1764	-22.5	13717	13566	-2027	- 8.5
-0.762	5021	4187	-2771	-33.5	14060	13726	-3043	-12.5
-1.016	5624	4371	-3539	-39.0	14800	14226	-4079	-16.0
-1.270	6391	4479	-4558	-45.5	14800	13993	-4818	-19.0
-1.524	6943	4416	-5357	-50.5	15200	14190	-5447	-21.0

TABLE 9. HORIZONTAL SCAN DATA SRD-41 (0.20° ROTATION)

Y / X (cm)	6.35 cm			
	U (μcm)	U_H (μcm)	U_V (μcm)	Θ
1.524	25563	24957	5533	12.5
1.270	23433	23040	4270	10.5
1.016	21630	21364	3384	9.0
0.762	20085	19935	2448	7.0
0.508	18746	18675	1634	5.0
0.254	18746	18743	327	1.0
0.000	18746	18743	- 327	- 1.0
-0.254	19393	19356	-1184	- 3.5
-0.508	19393	19303	-1859	- 5.5
-0.762	21630	21512	-2261	- 6.0
-1.016	22495	22218	-3519	- 9.0
-1.270	23433	22962	-4672	-11.5
-1.524	24452	23383	-7149	-17.0

NOTE: Data at 8.89 cm out of range.

APPENDIX

COMPUTER CODES

Program Name:	SCAN
Program Function:	To evaluate interferograms, compute horizontal and vertical components of displacement as well as total displacement.
Input:	1) Stage to be advance - x-direction or y-direction 2) Stage Increment - Distance moved between scan points 3) Film scale factor - Ratio of real object to image on interferogram 4) Distance to diffuser screen - Distance from interferogram to diffuser screen 5) Displacement - Distance measured manually between fringes 6) Angle - Angle of orientation of fringes
Output:	1) - Total Distance from Initial Scan Point 2) - Total Displacement 3) - Horizontal Component of Displacement 4) - Vertical Component of Displacement

```
      COMMON DD (2,200)
      WRITE(5,1)
    1 FORMAT ('MANUAL YOUNG FRINGE ANALYZER')
      WRITE(5,2)
    2 FORMAT ('STAGE TO BE ADVANCED?  0=X, 1=Y)')
      READ(5,3) IA
    3 FORMAT(I1)
      WRITE(5,4)
    4 FORMAT('STAGE INCREMENT?')
      READ(5,5) IC
    5 FORMAT(I4)
      WRITE(5,6)
    6 FORMAT('FILM SCALE FACTOR?')
      READ(5,7) SF
    7 FORMAT(F10.0)
      WRITE(5,17)
   17 FORMAT('DISTANCE FROM INTERFEROGRAM TO DIFFUSER SCREEN?')
      READ(5,7) X
      ICC=0
    8 ICC=ICC+1
      ICP=ICC-1
      WRITE(5,9)
    9 FORMAT('DISPLACEMENT?')
      READ(5,7) D
      WRITE(5,10)
   10 FORMAT('ANGLE?')
      READ(5,7) A
      A=A*3.14159/180.
      IF(D.EQ.0) GOTO 13
      IF(D.LT.0) GOTO 15
      U=(SF*.0000249133*X)/D
      U1=U*COS(A)
      U2=U*SIN(A)
      H=FLOAT((ICC-1)*IC)*.001
      WRITE(5,11) H,U,U1,U2
   11 FORMAT(3H H=,F10.3,5X,2HU=,F12.6)
      13HU1=,F12.6,5X,3HU2=,F12.6)
   12 DD(1,ICC)=U1
      DD(2,ICC)=U2
      GOTO 14
   13 DD(1,ICC)=0.
      DD(2,ICC)=0.
   14 IF(IA.EQ.1) CALL YADV(IC,5)
      IF(IA.EQ.0) CALL XADV(IC,5)
      GOTO 8
   15 ICC=(1-ICC)YIC
      IF(IA.EQ.1) CALL YADV(ICC,5)
      IF(IA.EQ.0) CALL YADV(ICC,5)
      WRITE(5,16)
   16 FORMAT('ANALYSIS ENDED')
      STOP
      END
```

```
SUBROUTINE YADV(IS,IR)
IS=NO. STEPS (+=FWD,-=REV)
IR=ADVANCE RATE OF STAGE
X=0
IF(IS.GT.0) GOTO 3
IF=IABS(IS)
DO 2 I=1,IP,1
CALL IPOKE("167772,"020000)
DO 7 K=1, IR,1
YSIN(X)CALL IPOKE ("167772,"000000)
DO 1 J=1,IR,1
Y=SIN(X)
CONTINUE
GOTO 6
CONTINUE
DO 5 II=1,IS,1
CALL IPOKE("167772,"010000)
DO 8 KK=1,IR,1
Y=SIN(X)
CALL IPOKE("167772,"000000)
DO 4 JJ=1,IR,1
Y=SIN(X)
CONTINUE
CONTINUE
RETURN
END
```

SCAN PROGRAM (CONTINUED)

```
SUBROUTINE XADV(IS,IR)
IS=NO. STEPS (+=FWD,-=REV)
IR=ADVANCE RATE OF STAGE
X=0
IF(IS.GT.0) GOTO 3
IP=IABS(IS)
DO 2 I=1,IP,1
CALL IPOKE("167772,"100000)
DO 7 K=1,IR,1
Y=SIN(X)
CALL IPOKE("167772,"000000)
DO 1 J=1,IR,1
Y=SIN(X)
CONTINUE
GOTO 6
CONTINUE
DO 5 II=1,IS,1
CALL IPOKE("167772,"040000)
DO 8 KK=1,IR,1
Y=SIN(X)
CALL IPOKE("167772,"000000)
DO 4 JJ=1,IR,1
Y=SIN(X)
CONTINUE
CONTINUE
RETURN
END
```

Program Name: Move

Program Function: To move translation stage and interferogram to initial scan position

Input: Input X,Y -Four digit value for positive or negative movement in X and Y directions

Output: Motion of translation stages
0.0025cm Incremental Movements
0.00025cm Reposition Accuracy

```
  3  WRITE(5,1)
  1  FORMAT('INPUT X,Y-214')
     READ(5,2) IX,IY
  2  FORMAT(214)
     IF(IX.EQ.O.AND.IY.EQ.O) GOTO 4
     CALL XADV(IX,5)
     CALL YADV(IY,5)
     GOTO 3
  4  CONTINUE
     STOP
     END
     SUBROUTINE YADV(IS,IR)
C    IS=NO.  STEPS (+=FWD,-=REV)
     IR=ADVANCE RATE OF STAGE
     X=0.
     IF(IS.GT.0) GOTO 3
     IP=IABS(IS)
     DO 2 I=1,IP,1
     CALL IPOKE("167772,"020000)
     DO 7 K=1,IR,1
  7  Y=SIN(X)
     CALL IPOKE("167772,"000000)
     DO 1 J=1,IR,1
  1  Y=SIN(X)
  2  CONTINUE
     GOTO 6
  3  CONTINUE
     DO 5 II=1,IS,1
     CALL IPOKE("167772,"010000)
     DO 8 KK=1,IR,1
  8  Y=SIN(X)
     CALL IPOKE("167772,"000000)
     DO 4 JJ=1,IR,1
  4  Y=SIN(X)
  5  CONTINUE
  6  CONTINUE
     RETURN
     END
     SUBROUTINE XADV(IS,IR)
C    IS=NO. STEPS (+=FWD,-=REV)
```

MOVE PROGRAM (CONTINUED)

```
C   IR=ADVANCE RATE OF STAGE
    X=0
    IF(IS.GT.0) GOTO 3
    IP=IABS(IS)
    DO 2 I=1,IP,1
    CALL IPOKE("167772,"100000)
    DO 7 K=1,IR,1
7   Y=SIN(X)
    CALL IPOKE("167772,"000000)
    DO 1 J=1,IR,1
1   Y=SIN(X)
2   CONTINUE
    GOTO 6
3   CONTINUE
    DO 5 II=1,IS,1
    CALL IPOKE("167772,"040000)
    DO 8 KK=1,IR,1
8   Y=SIN(X)
    CALL IPOKE("167772,"000000)
    DO 4 JJ=1,IR,1
4   Y=SIN(X)
5   CONTINUE
6   CONTINUE
    RETURN
    END
```

REFERENCES

1. Vandiver, T. L., "Whole-Field Experimental Stress Analysis Using Laser Speckle Interferometry", U.S. Army Missile Lab, Redstone Arsenal, Alabama, Technical Report No. RL-81-10, 14 Feb 1981.

2. Leendertz, J., "Interferometric Displacement Measurement of Scattering Surfaces Utilizing Speckle Effect," Journal of Physics E, Vol. 3, 1970, p.214.

3. Leithold, L., "The Calculus with Analytic Geometry", Harper and Row, 1972.

4. Mullinix, B. R., Ranson, W. F., Swinson, W. F., and Cost, T. L., "Quantification of Flaws in Fibered Composite Structures Using Interferometric Fringe Patterns," U.S. Army Missile Command, Redstone Arsenal, Alabama, Technical Report RL-76-18, 20 April 1976.

5. Swinson, W. F., "Acoustical Holography and Acoustical Interferometry with Young's Fringes", U.S. Army Missile Lab, Redstone Arsenal, Alabama, Technical Report RL-82-1, 5 October 1981.

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