Time-Dependent Restrained Boundary Condition Simulation

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Abstract

The study of transient forces and displacement is a common topic in the analysis of structural and machinery dynamics. Widely used analysis tools are the MSC/NASTRAN Version 64 Solutions 27, 31, 72, and 99. One limitation of this program is that time-dependent restrained mechanisms can not be directly modelled. In this paper, a method will be described to address this problem.

The latch in a gun barrel recoil system represents a time-dependent restrained boundary condition. The time domain was divided into two parts. In the first, latch reaction forces were computed assuming that the latch was restrained. The output for this case was then used as input for the solution of the second portion of the transient ayalysis. Here, the latch dynamics were computed assuming that the reaction forces are reset to zero at the time of latch release. The computed restraining forces and the results show that the procedure is a convenient method for analyzing time-dependent restrained boundary conditions.

I Introduction

Enforced motion boundary condition is described in MSC/NASTRAN Theoretical Manual [1] and Application Manual [2] . Automated procedures have been developed that allow the user to easily define time-dependent displacement, velocity, and acceleration boundary conditions. Enforced motion boundary conditions are widely used and accepted.

In this paper, a procedure is described to extend the use of the enforced motion boundary condition to simulate a time-dependent restrained boundary condition. The focus will be on a procedure that converts a time-dependent restrained condition to a time-dependent force condition which can be solved by MSC/NASTRAN.

The problem to be examined involves the latch mechanism of a gun. A 105 mm 60 caliber gun barrel is latched by a set of sliding pins. The pins have dual functions — one is to guide the barrel during recoil, and the other is to counter the barrel rotation forces generated by the projectile's reaction against the barrel rifling.

Since limited space is available in a recoil system, shorter sliding pins are desireable. The primary goal of the study is to evaluate the effects of the shorter pins on gun performance. The objective of the computer simulation is to determine the maximum angular velocity of the barrel when the latch is released.

II Gun Barrel Rotation Analysis

Figure 1 shows a sketch of the gun barrel and a corresponding beam model. The latch pins, breach block, and recoil mechanisms are located at the left end of the barrel and are modelled as a single lumped mass distributed at the end section of the barrel. Twenty-two beam elements and twenty-three nodes are used to model the barrel structure.

The analysis required two separate runs of MSC/NASTRAN Solution 27, direct transient analysis. The first run generates a reaction force at the latch located at node 1. MSC/NASTRAN bulk data is shown tabulated in Figure 2. Node 1, the latch, is fixed. Transient torque which is caused by the reaction of the projectile against the barrel rifling is applied at the barrel tip (node 23). In Figure 2, the rotation torque is entered in TABLED1-11. The latch reaction torque computed by MSC/NASTRAN are depicted in Figure 3. Figure 4a through 4d are MSC/NASTRAN plots of angular accelation, velocity, displacement, and torque at various locations, respectively.

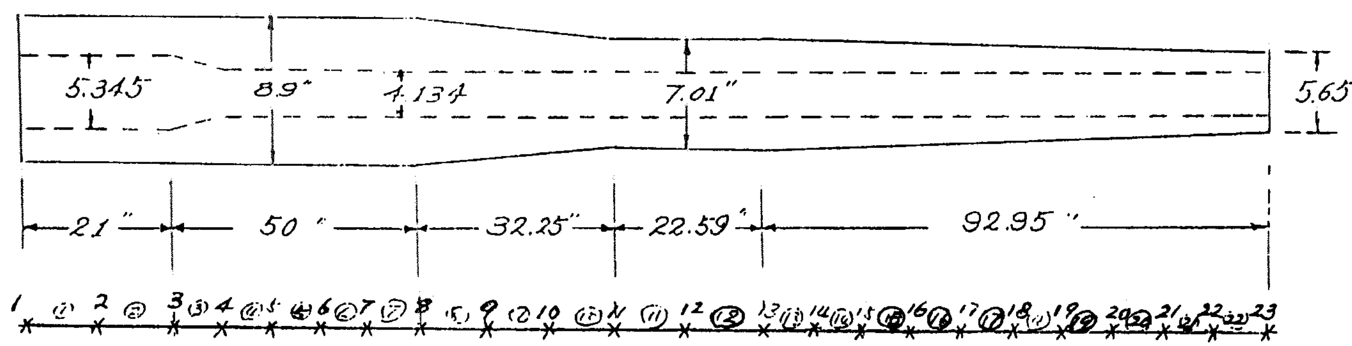

Figure 1. Gun Barrel Model

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	1	2	3	4	5	6	7	8	9	10
1-	CBEAM	1	1	1	2		1.			
2-	CBEAM	2	1	2	3		1.			
3-	CBEAM	3	2	3	4		1.			
4-	CBEAM	4	3	4	5		1.			
5-	CBEAM	5	3	5	6		1.			
6-	CBEAM	6	3	6	7		1.			
7-	CBEAM	7	3	7	8		1.			
8-	CBEAM	8	4	8	9		1.			
9-	CBEAM	9	4	9	10		1.			
10-	CBEAM	10	4	10	11		1.			
11-	CBEAM	11	7	11	12		1.			
12-	CBEAM	12	7	12	13		1.			
13-	CBEAM	13	8	13	14		1.			
14-	CBEAM	14	9	14	15		1.			
15-	CBEAM	15	10	15	16		1.			
16-	CBEAM	16	11	16	17		1.			
17-	CBEAM	17	12	17	18		1.			
18-	CBEAM	18	13	18	19		1.			
19-	CBEAM	19	14	19	20		1.			
20-	CBEAM	20	15	20	21		1.			
21-	CBEAM	21	16	21	22		1.			
22-	CBEAM	22	17	22	23		1.			
23-	CMASS2	90	337.	1	4					
24-	DAREA	1	23	4	1.					
25-	DAREA	2	1	4	1.					
26-	DELAY	13	1	4	-0.0003					
27-	DLOAD	30	1.	1.	10	1.	50			
28-	EIGR	20	MGIV	0.	1000.					+EI1
29-	+EI1	MASS								
30-	GRID	1		0.	0.	0.				
31-	GRID	2		10.5	0.	0.				
32-	GRID	3		21.	0.	0.				
33-	GRID	4		31.	0.	0.				
34-	GRID	5		41.	0.	0.				
35-	GRID	6		51.	0.	0.				
36-	GRID	7		61.	0.	0.				
37-	GRID	8		71.	0.	0.				
38-	GRID	9		81.75						
39-	GRID	10		92.5						
40-	GRID	11		103.25						
41-	GRID	12		114.545						
42-	GRID	13		125.84						
43-	GRID	14		135.135						
44-	GRID	15		144.43						
45-	GRID	16		153.725						
46-	GRID	17		163.02						
47-	GRID	18		172.315						
48-	GRID	19		181.61						
49-	GRID	20		190.905						
50-	GRID	21		200.2						
51-	GRID	22		209.495						
52-	GRID	23		218.79						
53-	MAT1	1	3.+7		.3	.283			.0012	
54-	PARAM	ASING	1							
55-	PARAM	AUTOSPC	YES							
56-	PARAM	COUPMASS	1							
57-	PARAM	G	0.06							
58-	PARAM	W3	187.03							
59-	PARAM	WTMASS	.00259							
60-	PBEAM	1	1	39.773	267.92	267.92		538.841		+P1
61-	+P1	NO	1.							
62-	PBEAM	2	1	39.773	267.92	267.92		538.841		+P2
63-	+P2	NO	1.	48.789	283.648	283.648		587.297		
64-	PBEAM	3	1	48.789	283.648	283.648		587.297		+P3
65-	+P3	NO	1.							
66-	PBEAM	4	1	48.789	283.648	283.648		587.297		+O1
67-	+O1	NO	1.	40.9157	265.23	265.23		530.461		
68-	PBEAM	5	1	40.9157	265.23	265.23		530.461		+O2
69-	+O2	NO	1.	33.0444	236.812	236.812		473.625		
70-	PBEAM	6	1	33.0444	236.812	236.812		473.625		+O3
71-	+O3	NO	1.	25.1721	208.394	208.394		416.789		
72-	PBEAM	7	1	25.172	104.197	104.197		208.394		+P4
73-	+P4	NO	1.							
74-	PBEAM	8	1	25.172	208.394	208.394		416.788		+O4
75-	+O4	NO	1.	23.8197	191.1232	191.1232		382.2453		
76-	PBEAM	9	1	23.8197	191.123	191.123		382.246		+O5
77-	+O5	NO	1.	22.4674	173.852	173.852		347.704		
78-	PBEAM	10	1	22.4674	173.852	173.852		347.704		+O6
79-	+O6	NO	1.	21.1151	156.581	156.581		313.162		
80-	PBEAM	11	1	21.1151	156.581	156.581		313.162		+O7
81-	+O7	NO	1.	19.7628	139.31	139.31		278.62		
82-	PBEAM	12	1	19.7628	139.31	139.31		278.62		+O8
83-	+O8	NO	1.	18.4105	122.039	122.039		244.078		
84-	PBEAM	13	1	18.4105	122.039	122.039		244.078		+O9
85-	+O9	NO	1.	17.0582	104.768	104.768		209.536		
86-	PBEAM	14	1	17.0582	104.768	104.768		209.536		+OA
87-	+OA	NO	1.	15.7059	87.4972	87.4972		174.994		
88-	PBEAM	15	1	15.7059	87.4972	87.4972		174.994		+OB
89-	+OB	NO	1.	14.3536	70.2264	70.2264		140.452		
90-	PBEAM	16	1	14.3536	70.2264	70.2264		140.452		+OC
91-	+OC	NO	1.	13.0013	52.9556	52.9556		105.91		
92-	PBEAM	17	1	13.0013	52.9556	52.9556		105.91		+OD
93-	+OD	NO	1.	11.649	35.6848	35.6848		71.3683		
94-	SPC1	1	12356	1						
95-	SUPORT	1	4							
96-	TABLED1	11								+TB1
97-	+TB1	0.	0.	.00019	5912.	.00065	28412.	.00098	54118.	+TB2
98-	+TB2	.00137	98403.	.00183	164079.	.00212	207336.	.00234	235055.	+TB3
99-	+TB3	.00253	251913.	.00276	263614.	.00289	265390.	.00308	262409.	+TB4
100-	+TB4	.00319	257959.	.00367	223922.	.00443	157445.	.00509	112857.	+TB5
101-	+TB5	.00568	83971.	.00678	51170.	.0074533	39468.	.0074533	0.	+TB6
102-	+TB6	10.	0.	ENDT						
103-	TABLED1	12								+T10
104-	+T10	.0	0.0	.0001	-.008590	.0002	-.135984	.0003	-1.05998	+T11
105-	+T11	.0004	-5.45687	.0005	-21.0060	.0006	-64.9148	.0007	-168.779	+T12
106-	+T12	.0008	-381.910	.0009	-771.730	.0010	-1421.20	.0011	-2424.60	+T13
107-	+T13	.0012	-3883.18	.0013	-5901.82	.0014	-8587.23	.0015	-12045.7	+T14
108-	+T14	.0016	-16383.3	.0017	-21703.9	.0018	-28108.0	.0019	-35689.6	+T15
109-	+T15	.0020	-44534.2	.0021	-54715.5	.0022	-66292.2	.0023	-79304.1	+T16
110-	+T16	.0024	-93767.9	.0025	-109675.	.0026	-126966.	.0027	-145630.	+T17
111-	+T17	.0028	-165486.	.0029	-186433.	.0030	-208243.	.0031	-230683.	+T18
112-	+T18	.0032	-253462.	.0033	-276249.	.0034	-298678.	.0035	-320359.	+T19
113-	+T19	.0036	-340880.	.0037	-359828.	.0038	-376786.	.0039	-391398.	+T20
114-	+T20	.0040	-403282.	.0041	-412148.	.0042	-417753.	.0043	-419928.	+T21
115-	+T21	.0044	-418572.	.0045	-413662.	.0046	-405243.	.0047	-393428.	+T22
116-	+T22	.0048	-378383.	.0049	-360368.	.0050	-339635.	.0051	-316513.	+T23
117-	+T23	.0052	-281360.	.0053	-264555.	.0054	-236482.	.0055	-207570.	+T24
118-	+T24	.0056	-178183.	.0057	-148717.	.0058	-119539.	.0059	-90998.7	+T25
119-	+T25	.0060	-63420.0	.0061	-37098.1	.0062	-12301.4	.0063	10738.07	+T26
120-	+T26	.0064	31819.89	.0065	50771.00	.0066	67455.56	.0067	81771.50	+T27
121-	+T27	.0068	93652.81	.0069	103070.5	.0070	110032.1	.0071	114580.7	+T28
122-	+T28	.0072	116782.4	.0073	116772.7	.0074	114651.7	.0075	110578.7	+T29
123-	+T29	.0076	104724.0	.0077	97268.75	.0078	88428.00	.0079	78454.31	+T30
124-	+T30	.0080	67647.69	.0081	56351.75	.0082	44919.70	.0083	33677.99	+T31
125-	+T31	.0084	22895.40	.0085	12768.55	.0086	3421.787	.0087	-5083.14	+T32
126-	+T32	.0088	-12732.9	.0089	-18547.2	.0090	-25565.1	.0091	-30833.2	+T33
127-	+T33	.0092	-35398.1	.0093	-38300.6	.0094	-42573.1	.0095	-45238.9	+T34
128-	+T34	.0096	-47312.7	.0097	-48803.0	.0098	-49714.1	.0099	-50048.7	+T35
129-	+T35	.0100	-48810.9	.0101	-49008.0	.0102	-47653.0	.0103	-45765.4	+T36
130-	+T36	.0104	-43372.7	.0105	-40510.2	.0106	-37221.4	.0107	-33556.9	+T37
131-	+T37	.0108	-28573.7	.0109	-25334.0	.0110	-20803.9	.0110	0.	+T38
132-	+T38	20.	0.	ENDT						
133-	TLOAD1	10	1			11				
134-	TLOAD1	50	2	13		12				
135-	TSTEP	100	200	.0001	1					
	ENDDATA									

TOTAL COUNT= 136

Figure 2. MSC/NASTRAN Bulk Data

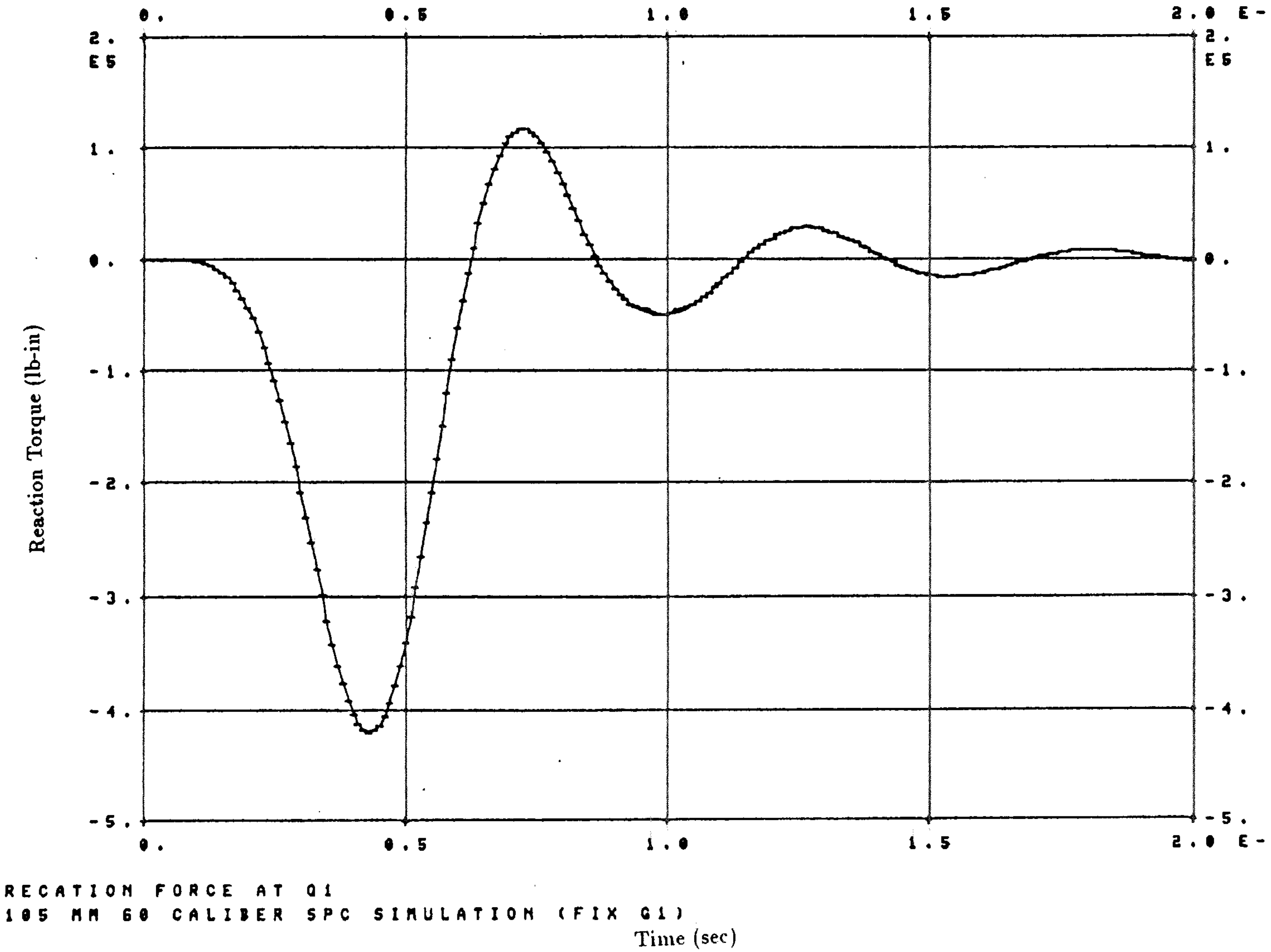

Figure 3. Reaction Torque at Latch

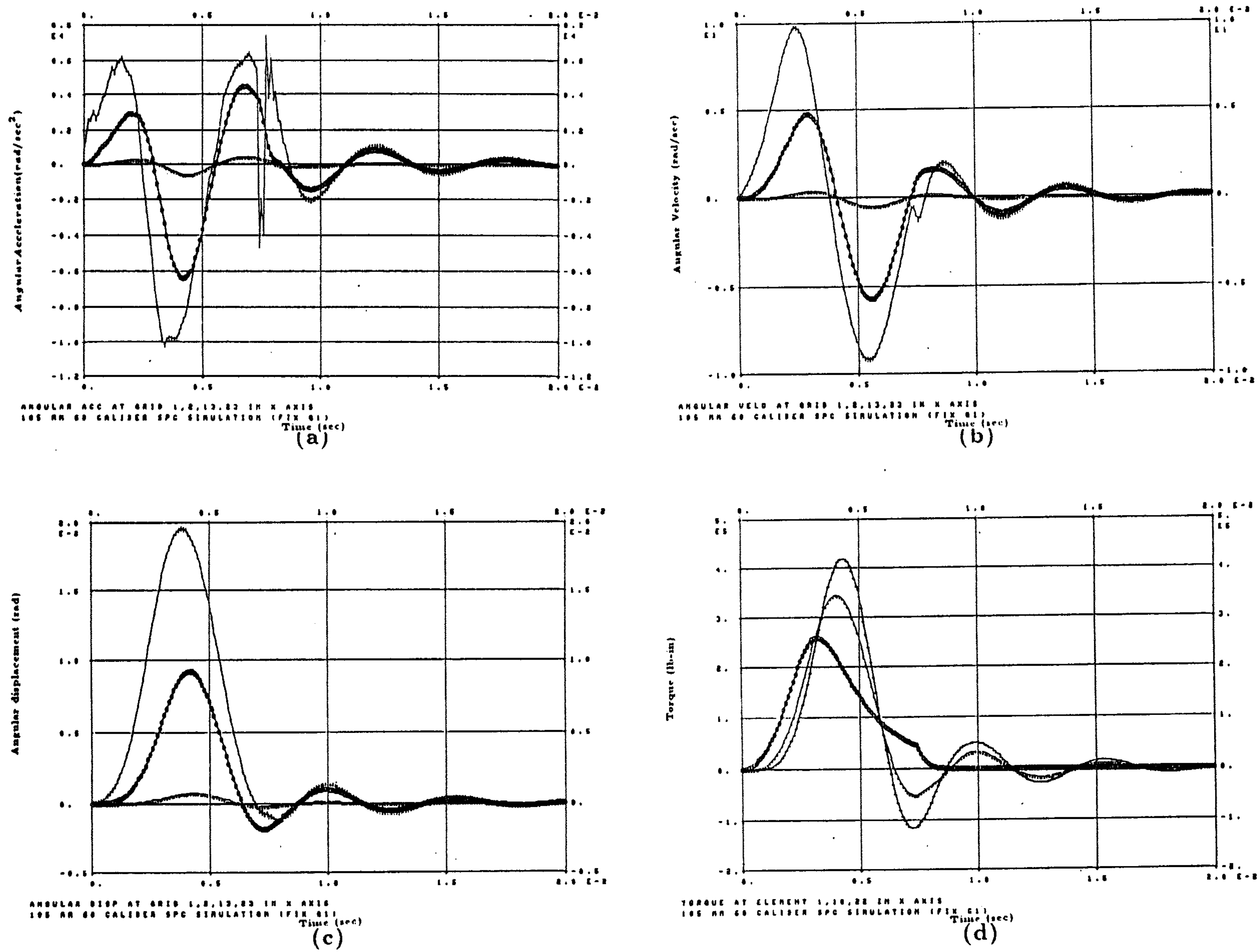

Figure 4. MSC/NASTRAN X-Y Plot, With Restrained Latch

Four symbols are used in each graph to represent different barrel locations corresponding to nodes or elements.

The second run applies the latch restraining forces computed in the first run to the latch location along with the rotation torque at the barrel tip. However, the restraining force is reset to zero when the latch is scheduled to release. Two release times are assumed — 0.011 and 0.013 sec. TABLED1-12, in Figure 2, contains the restraining force input data for the case where the latch is released at 0.011 sec. A three time step advance is included in the restraining force which was recorded in the first run. The time advance is required to compensate for a time lag created by the MSC/NASTRAN automatic procedure [2] .

Figures 5 and 6 depict MSC/NASTRAN solutions for the latch release at 0.011 sec. and 0.013 sec., respectively.

III Conclusions

The principle steps in the analytic procedure developed for time dependent restrained boundary conditions are summarized below:

1. Calculate the reaction forces with restrained boundary conditions.

2. Replaced the restrained boundary condition with an enforced boundary condition calculated from step 1. The enforced condition is modified to account for the release of the restrained condition.

Acceleration, velocity, and displacement solutions obtained with the restrained boundary condition and those corresponding to the enforced boundary condition were in good agreement during the restrained period. Minor discrepancies are caused by numerical truncation error and time step size.

A three time steps advance for the enforced condition is required to compensate for the time lag in the records generated by the MSC/NASTRAN's automated precedures.

In conclusion, this two step procedure can be easily utilized with the MSC/NASTRAN to analyze time-dependent restrained boundarys.

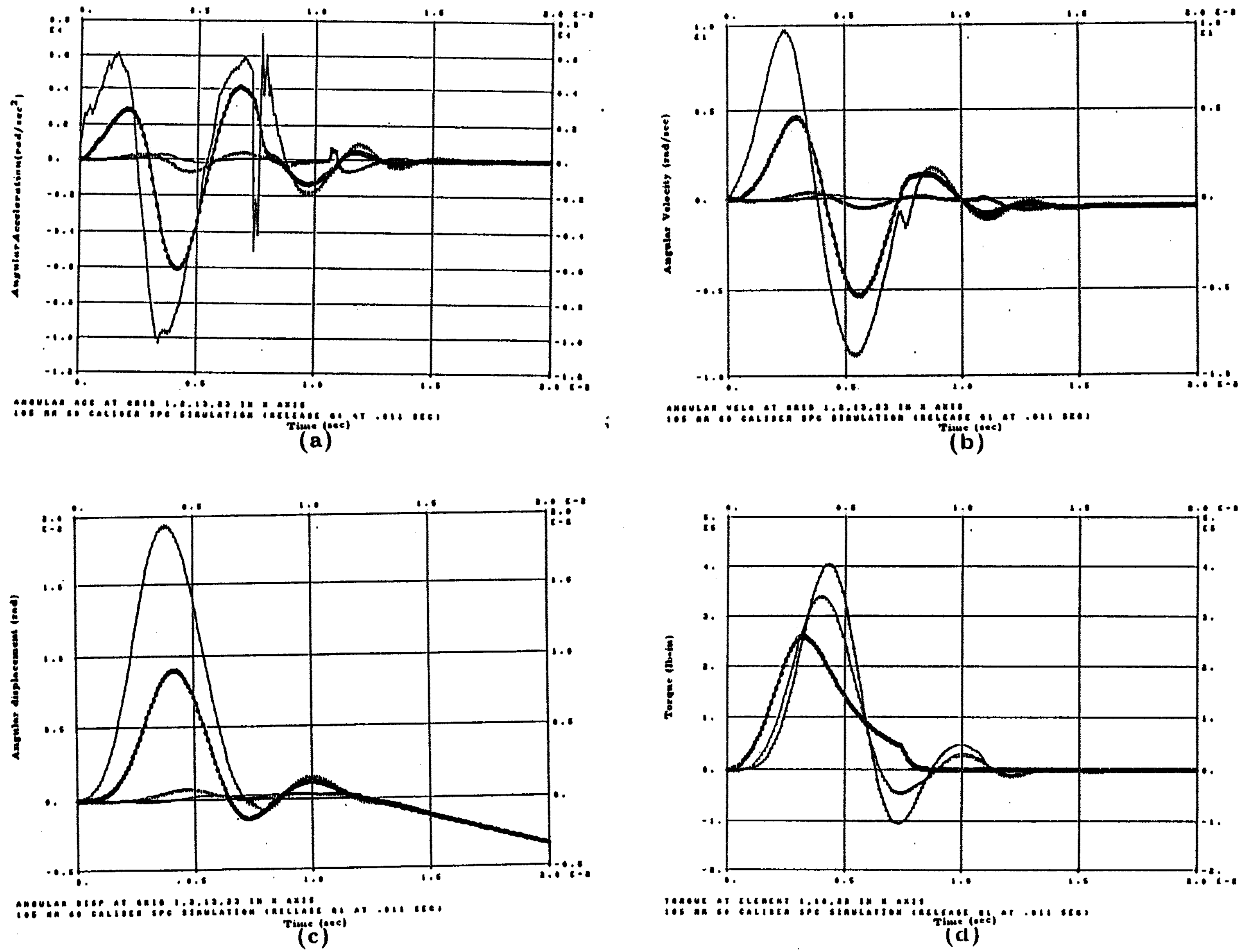

Figure 5. MSC/NASTRAN X-Y Plot,Latch Release at .011 sec

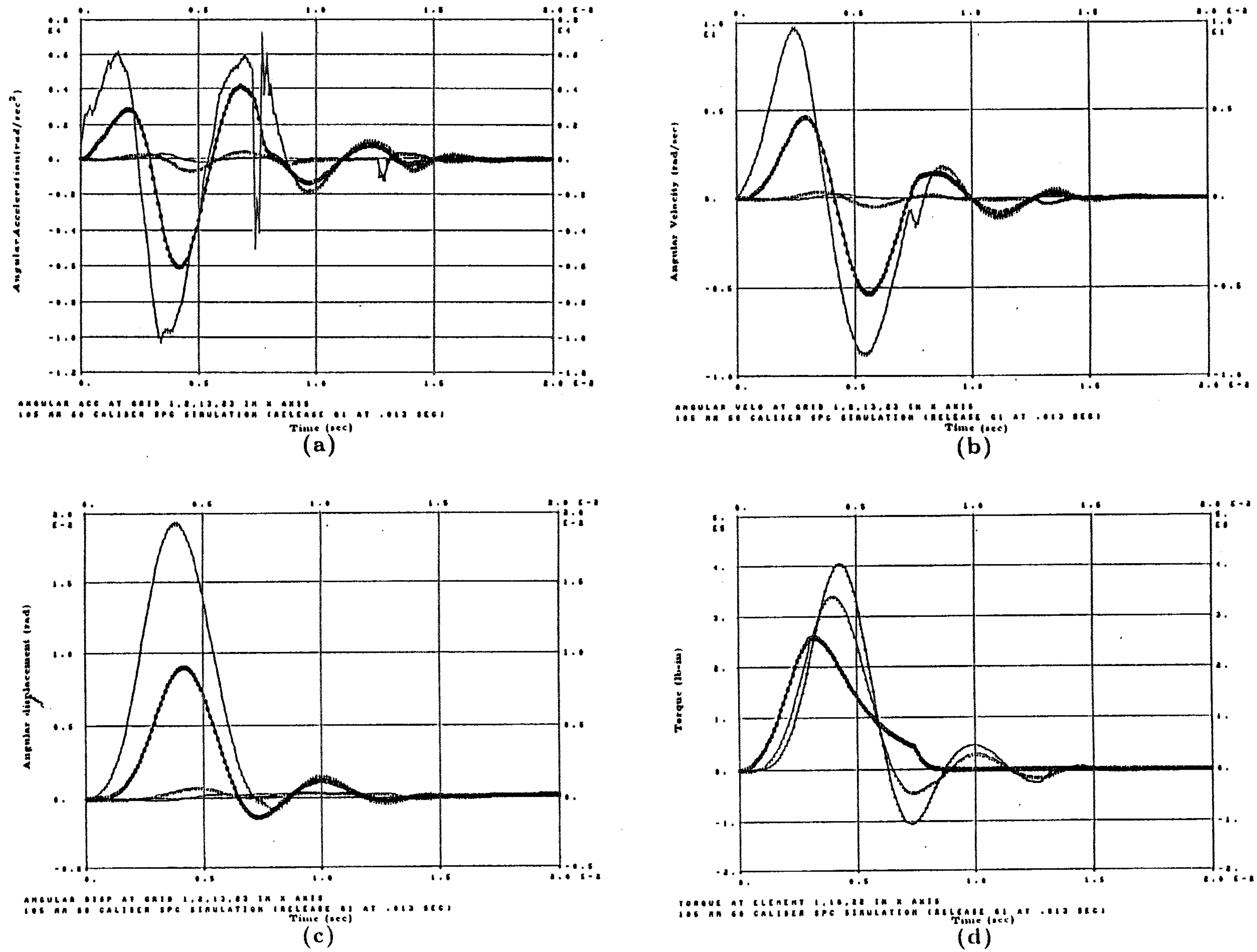

Figure 6. MSC/NASTRAN X-Y Plot, Latch Release at .013 sec

References

[1] Joseph, J. A., Editor, "NASTRAN Theoretical Manual", The MacNeal-Schwendler Corporation, Los Angles, CA, September 1973, Sections 11,12.

[2] Joseph, J. A., Editor, "NASTRAN Application Manual" The MacNeal-Schwendler Corporation, Los Angles, CA, September 1987, Section 2.7.