

The CML Dynamic Load/Unload Simulator (Version 421.10)

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Abstract

This report presents a brief description of the dynamic load/unload (L/UL) simulator developed at the Computer Mechanics Laboratory at the University of California at Berkeley. The CML Air Bearing Dynamic Simulator was modified to implement a simplified model of suspension assemblies in order to provide a numerical analysis of L/UL processes. Two types of suspensions, one with a dimple and another without a dimple, can be simulated with both positive and the so-called negative pressure sliders. Five typical examples are presented. One example shows that positive pressure sliders can also possibly hit the disks during unload because of the effects of the skew angle, which causes sub-ambient pressure zones. Another example demonstrates that negative pressure sliders mounted on a suspension for which the flexure is constrained to prevent the dimple separation can have even stronger oscillations during unload than what occurs without the constraint. A group of post-process programs written in MATLAB is provided. This simulator is very useful for evaluating the L/UL performance of various designs of air bearing surfaces and suspension-flexure systems.

1 Introduction

This report is a brief manual for the dynamic load/unload (L/UL) simulator developed at the Computer Mechanics Laboratory at the University of California at Berkeley. The dynamic L/UL process is mainly determined by the air bearing dynamics as well as the suspension dynamics. Therefore, the main part of the dynamic L/UL simulator is the CML air bearing dynamic simulator [1]. A simplified L/UL model for the suspension system, which was fully described in our previous report [2], is implemented in the simulator. Before users can implement this new simulator, they need to carefully study and be well familiar with these two reports [1,2]. Knowledge of and experience with suspension dynamics is extremely important for users to prepare the suspension parameters that are used in the L/UL simulation.

The L/UL simulator has the following features:

- 1) All features of the air bearing dynamic simulator are retained. Some features can be combined together to simulate a complicated process. For example, the effects of disk run-out on L/UL can be simulated by using disk flutter.
- 2) Both load and unload processes can be simulated.
- 3) The suspension assemblies are modeled by springs and dampers. Two types of suspension assemblies can be modeled. The first type has a gimbal, and its parameters would be changed at the dimple separation during the L/UL process. The second type has an integrated gimbal and no dimple. During the L/UL process, its parameters will not be changed.
- 4) Positive and negative pressure sliders can be simulated.

- 5) The contact between the slider and the disk is modeled by asperity contacts. The contact at the dimple is modeled by discontinuous changes of the parameters. It is obvious that these contact models are not perfect. Therefore, the result has only qualitative meanings if contacts occur. It is difficult to find an accurate method to simulate contacts.

2 Installation and file structures

The file *CML_d421d10.tar.gz* is a Unix compressed archive file. After using the Unix command:

```
gunzip CML_d421d10.tar.gz
```

```
tar -xvf CML_d421d10.tar
```

you will get the following directories and files under the *CML_dlul* directory.

- 1) Directory *SRC_DEC* contains the FORTRAN source code *d421d10.f* and two included files (*.bi) for the DEC Alpha machine. The *d421* means this simulator is modified from the CML air bearing dynamic simulator version 4.21, and the *d10* means this is the dynamic L/UL simulator version 1.0.
- 2) Directory *SRC_IBM* contains the FORTRAN source code *d421d10.f* and two included files for IBM machines.
- 3) Directory *mfiles* contains MATLAB m-files for post-processing. The function of these files will be described in a later section.
- 4) Directory *example1* contains input files and results of the unload process for a negative pressure slider incorporating the first type of suspension.

- 5) Directory *example2* contains input files and results of the unload process for a positive pressure slider with the first type of suspension. You will find that it is possible for the positive pressure sliders that the dimple will also be separated and the slider can hit the disk during the unload process, because of the effects of a sub-ambient pressure caused by the skew angle.
- 6) Directory *example3* contains input files and results of the load process for a negative pressure slider. The time step will significantly affect the simulation because the slider hits the disk.
- 7) Directory *example4* contains input files and results of the load process for a negative pressure slider.
- 8) Directory *example5* contains input files and results of the unload process for a negative pressure slider incorporated with the suspension for which the dimple cannot be separated.

The FORTRAN source code should be compiled by a suitable FORTRAN compiler in directory SRC_DEC or SRC_IBM to obtain an executable file *d421d10*. The executable file *d421d10* is copied to directory *CML_dlul*. To run a simulation, e.g., the *example1*, you should change the current directory to *example1* and type *../d421d10*. To display the results, you can run MATLAB in the current directory, and type the command in the MATLAB environment

```
>> path(path, './mfiles')
```

Then, you can use the m-files to display the results in MATLAB. For example, by typing

```
>> force1g(0,0)
```

you will obtain the force history during the L/UL process in gram units.

3 Procedure

The procedure for L/UL simulation is as follows:

- 1) Design the air bearing surfaces or input the air bearing designs by using the CML air bearing design program [3]. Create the *rail.dat* file in Quick300 or Quick400 format.
- 2) Edit the L/UL simulator input file *dynamics.def*. The simple way is to copy this file from the examples and modify the related parameters.
- 3) Find the flying attitudes in the steady state, and create the grid.

The following procedure is suggested. Use the design code to obtain the initial flying attitudes in the steady state. Then, run no L/UL ($L/UL = 0$ in the *dynamics.def* file as described in the next section) simulation ($dt=1e-6$, $tf=.5-10e-3$, $iadpt=1$, $ioldgrid=0$). The flying attitudes in the steady state can be found from the last line of the output file *fhist.dat*, and the grid is also obtained and has been saved in files *x.dat* and *y.dat*. Finally, remember to change $iadpt=0$, $ioldgrid=1$, and specify dt , tf and L/UL to the required values for the L/UL simulation.

- 4) Perform the L/UL simulation. It is very time consuming.
- 5) Display the results by using the MATLAB m-files that are included in this simulator.

4 Input and output data files

4.1 Input file *rail.dat*

The file *rail.dat* defines the rail shape and air bearing surface. This file is generated by the CML design code [3]. The four points of interested are specified in this file. The

flying height of these four points will be calculated in the L/UL simulation. It is suggested that the four points be specified as the four corners of the slider, such that it is easy for you to identify which corner hits the disk if it happens during the L/UL.

4.2 Input file dynamics.def

```

*****Problem Definition*****
xl(m)      yl(/xl)    xg(/xl)    yg(/xl)    zg(/xl)    halt
0.200e-2   0.800      0.5        0.0        0.105      0.0
f0(kg)   xf0(xl)    yf0(/yl)  amz        aip        air
0.35e-2   0.5          0.0 0.5951888e-5  0.2176109e-11 0.1361445e-11
rpm      dt(s)    tf(s)    ra        ra_if      ra_of
5400.0   1e-6      50e-3    45e-3     22.0e-3   47.0e-3
*****Suspension*****
iact       xact(m)    dact       vact       ske
1          38.00e-3  0.0        0.0        18.0
isusp      nmodes     ncg         alfa        beta
0         10        1000       60.0       1.0e-5
skz        skp        skr         scz         scp         scr
27.0       1.146e-4  1.432e-4   .002       1.579e-8   1.396e-8
*****Initial Flying Condition*****
hm(m)    hp(rad)   hr(rad)   vz(m/s)   vp(rad/s) vr(rad/s)
0.347484E-07 0.227865E-03 -.225693E-04 0 0 0
*****Solution Control*****
iqpo       akmax      emax       idisc
5          1.0e-10   1.0e-4     1
*****Grid Control*****
iadapt   isymmetry  ioldgrid  nx  ny  nsx  nsy
0         0          1         82  82  1    1
xnt(i),i=2,nsx
  0.0
nxt(i),i=2,nsx
  0
dxr(i),i=1,nsx
  1.0
ynt(i),i=2,nsy
  0.0
nyt(i),i=2,nsy
  0
dyr(i),i=1,nsy
  1.000000
difmax     decay      ipmax
40.0       40.0      0
*****Point by Point Disk Track Profile*****
ims        nfx        dinit
0          4096      3.2
*****Numerical Generation of Disk Surface Topography*****
nwave     nzone     nasper
0         0         0
iwttype  wamp(m)  wang(dg)  wthx(m)  wthy(m)  wpx(m)  wpy(m)  wrs(m)  wre(m)
zr1(m)   zh1(m)   zr2(m)    zh2(m)   zr3(m)   zh3(m)

```

```

iatype aamp(m) aang(dg) alocx(m) alocy(m) asizx(m) asizy(m)
****Numerical Generation of Slider Surface Topography****
nswave nsasper
0      0
istype swamp(m) swng(dg) swthx(m) swthy(m) swpdx(m) swpdy(m)
isatype saamp(m) saang(dg) salocx(m) salocy(m) sasizx(m) sasizy(m)
*****Track Accessing Motion*****
nap
0
tac(s)  aac(rad/s^2)
*****Time-Dependent Disk Velocity*****
nvp
0
tvp(s)  vtd(RPM)
*****Sinusoidal Disk Flutter*****
iflut  tsft    teft    fqft    amft
0      0      0.003  10000.0  10.0e-9
*****Asperity Contact*****
icmod  ey      ydst    pratio  frcoe
2      9.7135e+10  28e+6   0.3     0.3
ncz
1
sikm(m) ceta(/m/m)  rasper(m) rcts(m)  rcte(m)  gldht
3.0e-9  2.0e+12      10.0e-9  10.0e-3  50.0e-3  2.0e-9
*****Dynamic Load/Unload *****
L/UL,  Susptype  kz1      amz      n/a      v(L/ULspeed,m/s)
2      0          276.5    .5951888e-5  0      50e-3
n/a,   n/a,   n/a,   n/a,   n/a,   fs1(gram),  fs2,   fs3,   fs4,   fs5
0      0      0      0      3.49d0  0.0d0  -.5d0  -1.0d0 -1.174d0
amz,   aip      air      dx/xl,n/a, n/a n/a n/a n/a n/a
.595189e-5  0.217611e-11 .136145e-11 -0.3  0  0  0  0  0
kz1,   kp1,   kr1,   kz2,   kp2,   kr2,   n/a, n/a, n/a, n/a
276.5  353.2e-6  117.4e-6  48.5  55.12e-6  83.08e-6  0  0  0  0
cz1,   cp1,   cr1,   cz2,   cp2,   cr2,   n/a, n/a, n/a, n/a
.47e-3  1.11e-9  5.06e-10  3.5e-4  4.38e-10  4.25e-10  0  0  0  0
n/a,   n/a,   n/a,   n/a,   n/a,   n/a n/a, n/a, n/a, n/a
0      0      0      0      0      0  0  0  0  0
*****End of Input Data*****

```

The file *dynamics.def* contains a large number of parameters. Most of them are the same as described in the report [1]. The parameters, which are important, different, or additional, and need more explanations, will be discussed in detail as follows.

f0 suspension normal load (kg).

rpm disk revolutions per minute. You can try different RMP to obtain the best L/UL performance.

dt time step (s). It will be significantly affect the results if contacts occur. In some situations, the calculation will be abnormally terminated for numerical overflow. This will be improved in the future version. However, users can change **dt** to prevent it. A smaller **dt** would be preferred when contacts occur.

tf total time duration (s) of the simulation. It is better to specify a larger value to let the simulator automatically stop after the convergence criterions are reached.

ra radial position of the slider's gravity center (m). We don't simulate the effects of the motion in the track seeking direction, so the position is the point at which the unload process is started, or the air flowing starts to affect the slider during the load process.

ske the skew angle (degree) at the specified radial position.

hm, hp, hr the initial nominal flying height (m), pitch and roll (rad) for load. The height is specified to the position at which the air flowing starts to affect the slider's motion. The suspension vibration effects can be simulated by specified different **hp** and **hr**. For unload, **hm, hp** and **hr** are the steady flying attitudes.

iadpt **1** = use adaptive grid to generate the grid; **0** = disable grid generation. Please read the previous section (procedure 3).

ioldgrid **1** = use the old grid saved in the *x.dat* and *y.dat* files; **0** = use adaptive grid. Please read the previous section (procedure 3).

nx, ny grid size in the x and y directions, respectively. Must be in the form of $16 \times n + 2$. These two parameters will significantly affect the accuracy and computation time of the simulation.

icmod Asperity contact model: **1**= GW model; **2**=elastic model. We use the asperity contact to approximately simulate the impact between the disk and the slider.

gldht glide height (m).

L/UL **0**=disable L/UL simulation; **1**=simulate the load process; **2**=simulate the unload process.

SuspType **0**=suspension with a dimple and the contact at the dimple could be separated.
1=suspension with no dimple.

kz1, kp1, kr1, cz1, cp1, cr1 Stiffness and damping parameters (units in N, m, s) in the vertical, pitch and roll directions of the suspension with no dimple or when the dimple is in contact.

kz2, kp2, kr2, cz2, cp2, cr2 Stiffness and damping parameters of the suspension when the dimple has separated.

v(L/ULspeed,m/s) the effective speed (m/s) of the L/UL mechanism in the Z direction.

dx/xl offset normalized with the slider length (**xl**) in the X direction after the dimple has separated. A negative value means offset toward the leading edge. This value will significantly affect the unload process. This value and stiffness can be calculated from a FE model of the suspension (including the effects of L/UL mechanism). The FE model should be verified by a modal experiment [4], and the damping parameters can be estimated from the experimental results.

amz, aip, air slider mass (kg), pitch and roll moments ($\text{kg}\times\text{m}^2$) of inertia, respectively.

fs1, fs2, fs3, fs4, fs5 air bearing forces (gram). The pressure profiles at these values will be output to files *preshx.dat* and *pressx.dat* ($x=1\sim 5$). You can use very large or very small values to prevent the output.

4.3 Output file *dload.dat*

This file contains ten columns:

Column	Contents
1	time (s)
2	Displacement at the effective L/UL point (m)
3	Displacement at the slider's L/UL point (m)
4	L/UL force (mgram)
5	Displacement at the slider's center (m)
6	Dimple separation (m)
7	Normalized positive bearing force center in the X direction
8	Normalized positive bearing force center in the Y direction
9	Normalized suction force center in the X direction
10	Normalized suction force center in the Y direction

4.4 Other output files

The *lduldpar.out* file contains some parameters that are defined in the *dynamics.def* file.

The *preshx.dat* files ($x=1\sim 5$) contains the time and air bearing force at that time the pressure profiles are saved to files *pressx.dat*. The data saved in these files can be displayed by the post-processing programs, such as *pressur1.m*, *pressur5.m*.

5. Post-processing and examples

There are fourteen MATLAB programs for post-processing. The *rail2d.m*, *rail3d.m*, *history.m* and *p3d.m* files have been described in report [1]. The other programs are as follows, where *nt1* is the start point number of time histories, *nt2* is the end point number of the time histories. *nt1=0* is the same as *nt=1*, and *nt2=0* is the same as setting *nt2* to the largest point number of the time histories. *np* is the point number of interested on the air

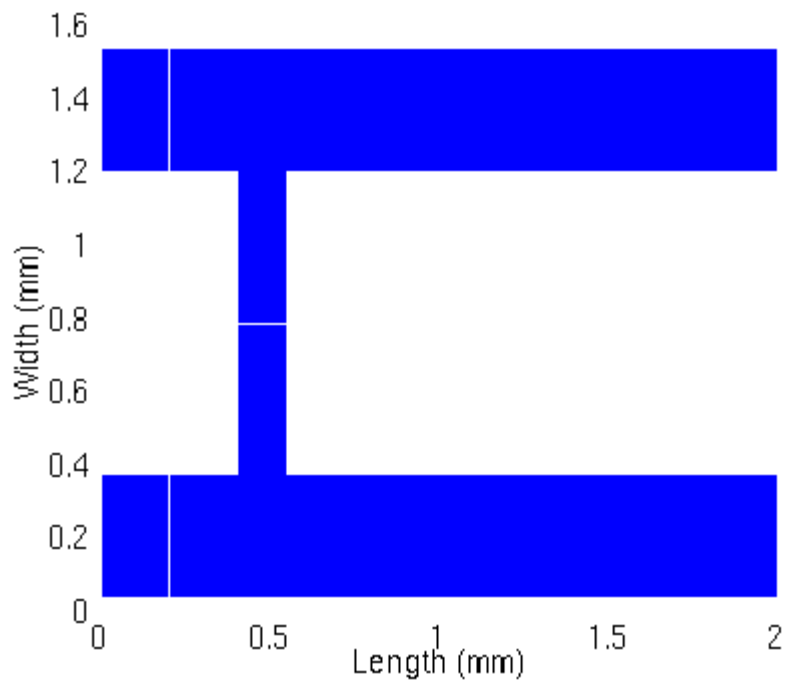
bearing surfaces of the sliders. $np=0\sim 5$. Using $np=0$, we can specify the point as the center of the trailing edge. The air bearing surfaces of the two sliders used in the examples are shown in Figure 1.

Name	command	Examples	descriptions
<i>force1g.m</i>	<code>force1g(nt1,nt2)</code>	Fig.2	Displays the air bearing force, positive and negative forces in one figure in gram units.
<i>force1n.m</i>	<code>force1n(nt1,nt2)</code>	Fig.3	Displays the air bearing force, positive and negative forces in one figure in Newton units.
<i>forcdsp6.m</i>	<code>forcdsp6(nt1,nt2)</code>	Fig.4&5	There are six figures arranged as Forces Air Bearing force center Force center in X Force center in Y Displacement Air Bearing and L/UL force
<i>fly4p.m</i>	<code>fly4p(nt1,nt2)</code>	Fig.6	There are six figures arranged as FH at point 1 FH at point 2 FH at point 3 FH at point 4 Pitch Roll
<i>flyzpr3.m</i>	<code>flyzpr3(np, nt1,nt2)</code>	Fig.7	There are three figures arranged as FH at point np Pitch Roll
<i>flyzpr5.m</i>	<code>flyzpr5(np,nt1,nt2)</code>	Fig.8	There are five figures arranged as Parameters Disk track Displacement at np FH at point np Pitch Roll
<i>dspld5.m</i>	<code>dspld5(nt1,nt2)</code>	Fig.9	There are six figures arranged as Parameters L/UL force L/UL displacement L/UL displ. at slider Displ. at slider center Dimple separation

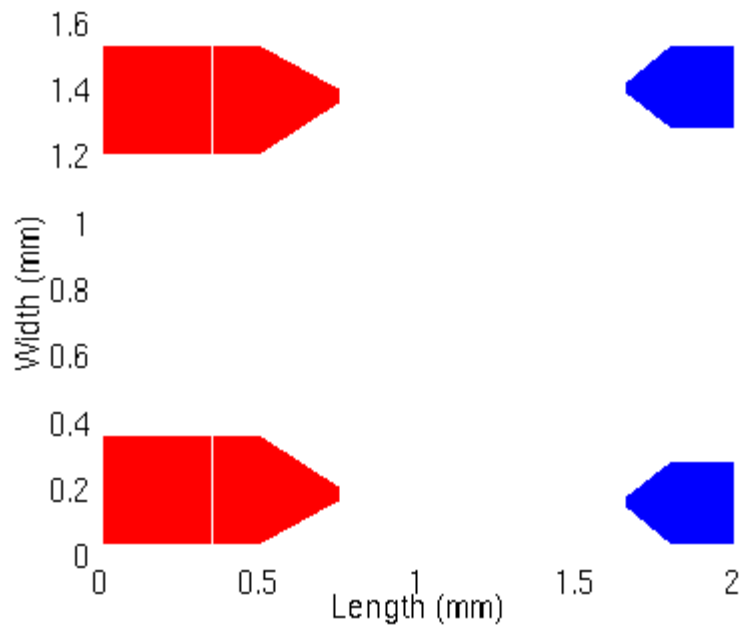
<i>force5.m</i>	<code>force5(nt1,nt2)</code>	Fig.10 There are five figures arranged as
		Parameters Air Bearing force
		Positive force Negative force
		Force center in X Force center in Y
<i>pressur1.m</i>	<code>pressur1(n)</code>	Fig.11 Display of the air bearing pressure profile at a specified force point n (n=1~5).
<i>pressur5.m</i>	<code>pressur5</code>	Fig.12 There are five pressure profiles arranged as
		Parameters at force fs1
		at force fs2 at force fs3
		at force fs4 at force fs5

Refernces

- 1 L.S. Chen, Y. Hu and D. B. Bogy, "The CML Air Bearing Dynamic Simulator Version 4.21", Technical Report No. 97-019, Computer Mechanics Laboratory, U. C. Berkeley, September 1997.
- 2 Q. H. Zeng, M. Chapin and D. B. Bogy, "Dynamics of the Unload Process for Negative Pressure Sliders", Technical Report No. 98-003, Computer Mechanics Laboratory, U. C. Berkeley, March 1998.
- 3 R. Grisso, S. Lu and D. B. Bogy, "CML Air Bearing Design Program (Version 4.0.17) and 32-bit Windows Interface," Technical Report No. 97-013, Computer Mechanics Laboratory, U. C. Berkeley, 1997.
- 4 Q. H. Zeng and D. B. Bogy, "Modal Dynamic Experiment and Analysis of a Suspension Assembly Used in Hard Disk Drives," Technical Report No. 96-013, Computer Mechanics Laboratory, U. C. Berkeley, May, 1996.



A) The Negative pressure slider



b) The Positive pressure slider

Figure 1 Two sliders used in the examples

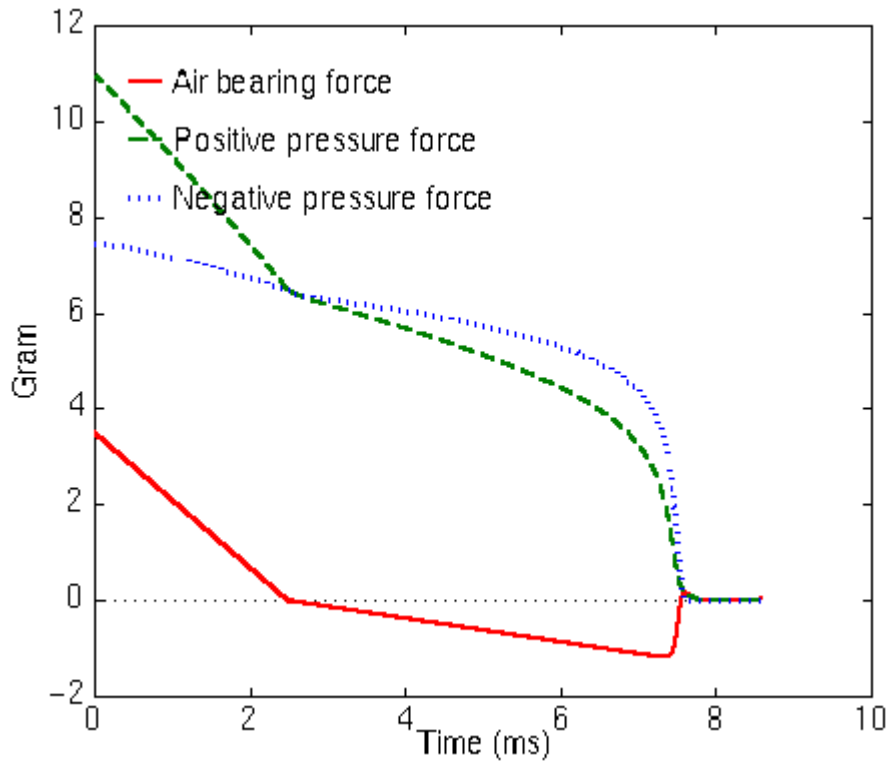


Figure 2 Air bearing force history of the negative pressure slider during unload process

in gram units.

(Example1) created by command *force1g(0,0)*

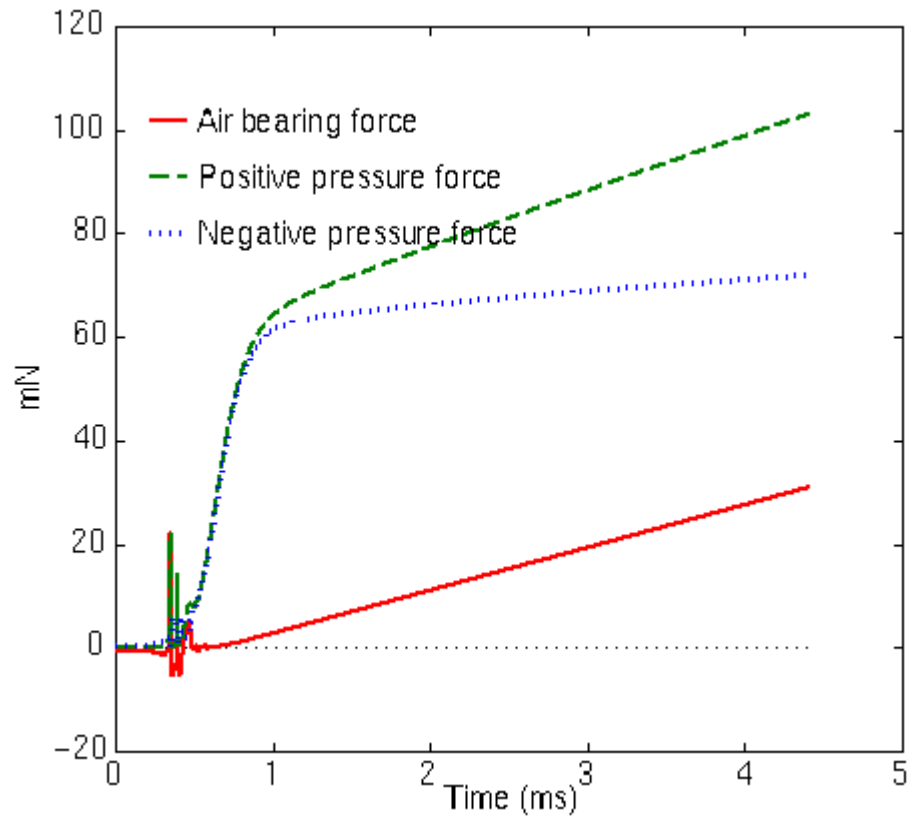


Figure 3 Air bearing force history of the negative pressure slider during load process in Newton units.

(Example3) created by command *forceIn(0,0)*

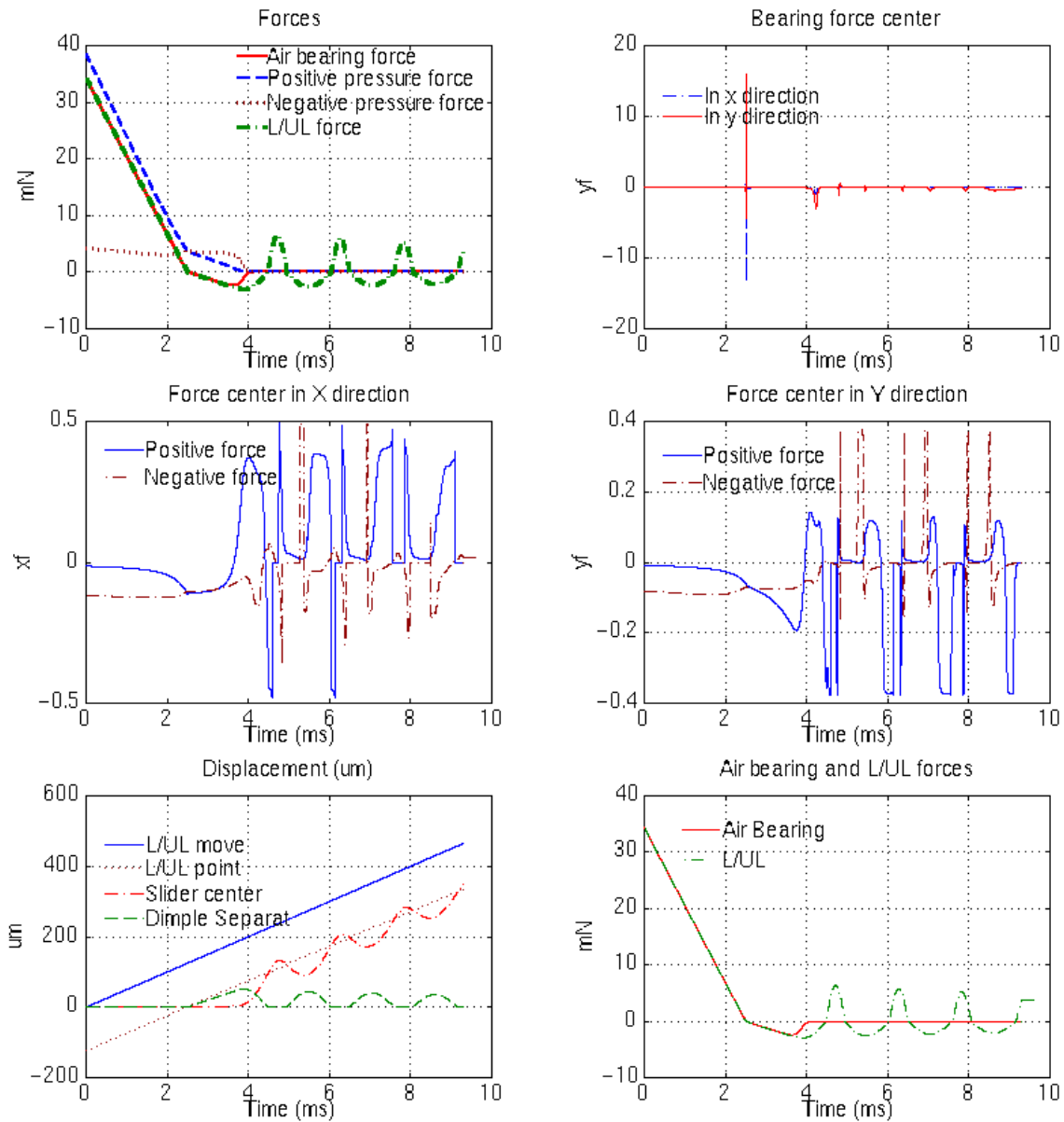


Figure 4 Forces and displacements history of the positive pressure slider during unload
 (We can see that the dimple separations occur during unload process for the positive slider, and it is possible for the slider to hit the disk)

(Example2) created by command *forcdsp6(0,0)*

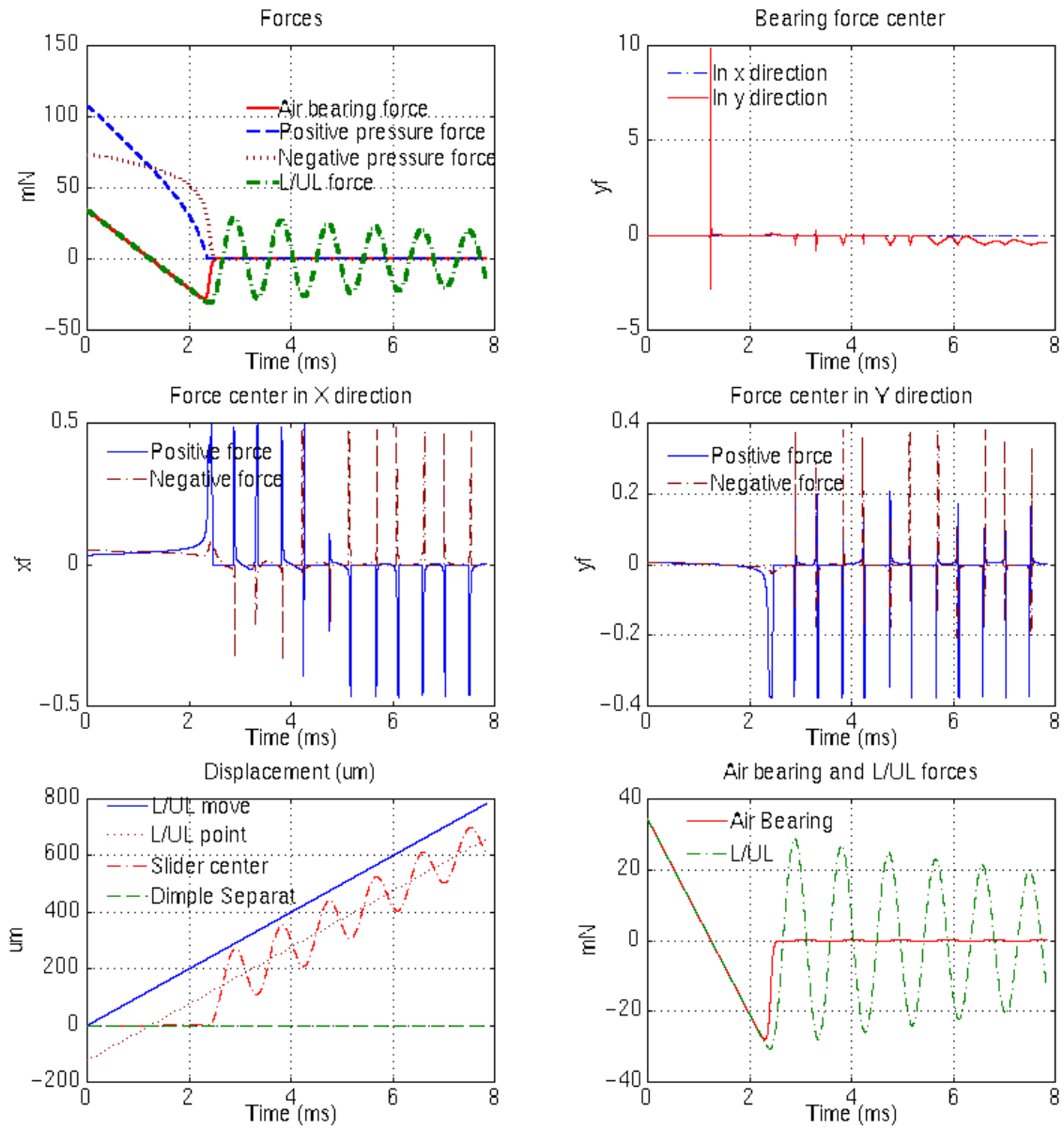


Figure 5 Force and displacement history of a negative pressure slider during unload

(We can see that the slider has an even stronger oscillation during unload for the suspension in which the gimbal is limited to prevent the dimple separation than in Example 1 where the separation is allowed.)

(Example5) created by command *forcdsp6(0,0)*

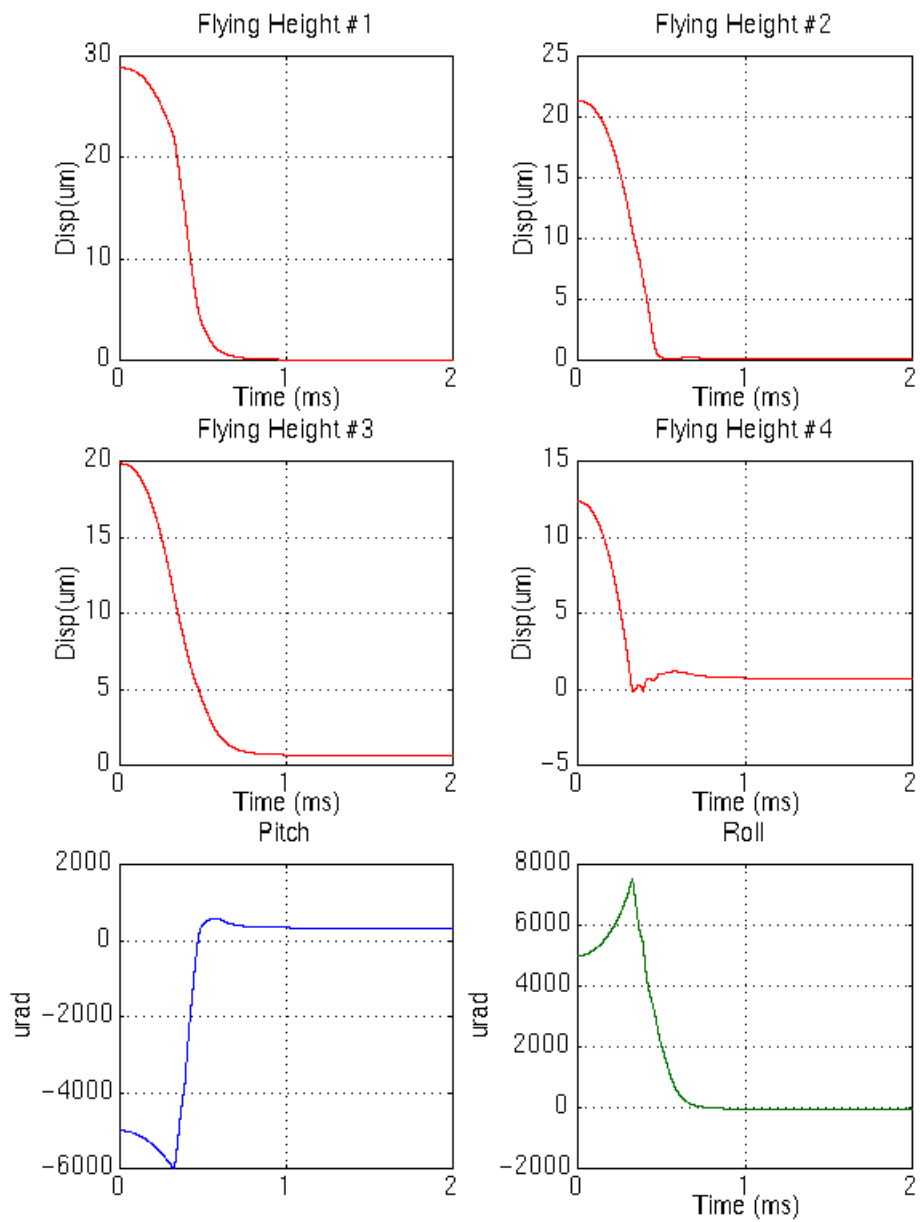
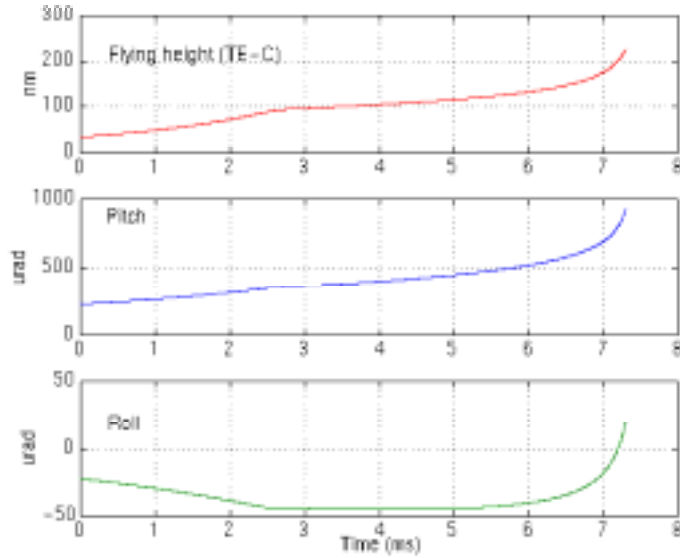


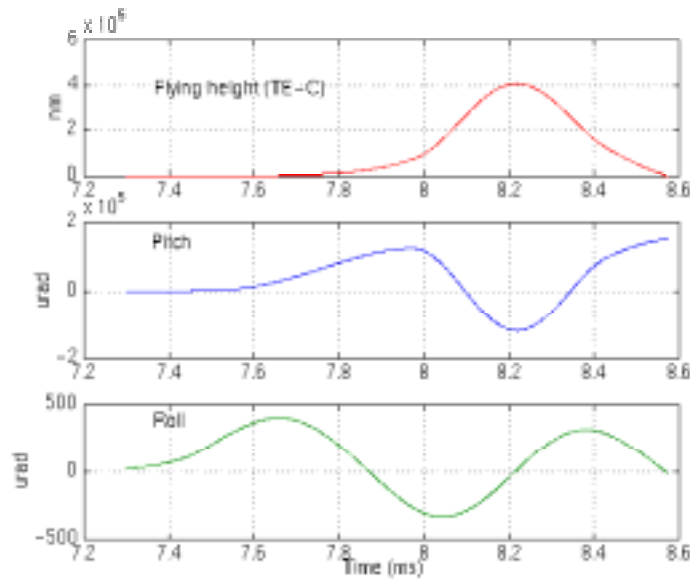
Figure 6 Flying attitude histories of the negative pressure slider during load

(We can see that the slider hits the disk at point # 4, and then quickly settles down)

(Example3) created by command *fly4p(0,4000)*



a) Stages 1 (dimple in contact) and 2 (dimple has separated) displayed by command `flyzpr3(0,0,7300)`



b) Stages 3 (air bearing quickly disappears) and 4 (slider vibrates on the suspension) displayed by command `flyzpr3(0,7300,0)`

Figure 7 Flying attitude histories of the negative pressure slider at the center of the trailing edge during the unload process (Example1)

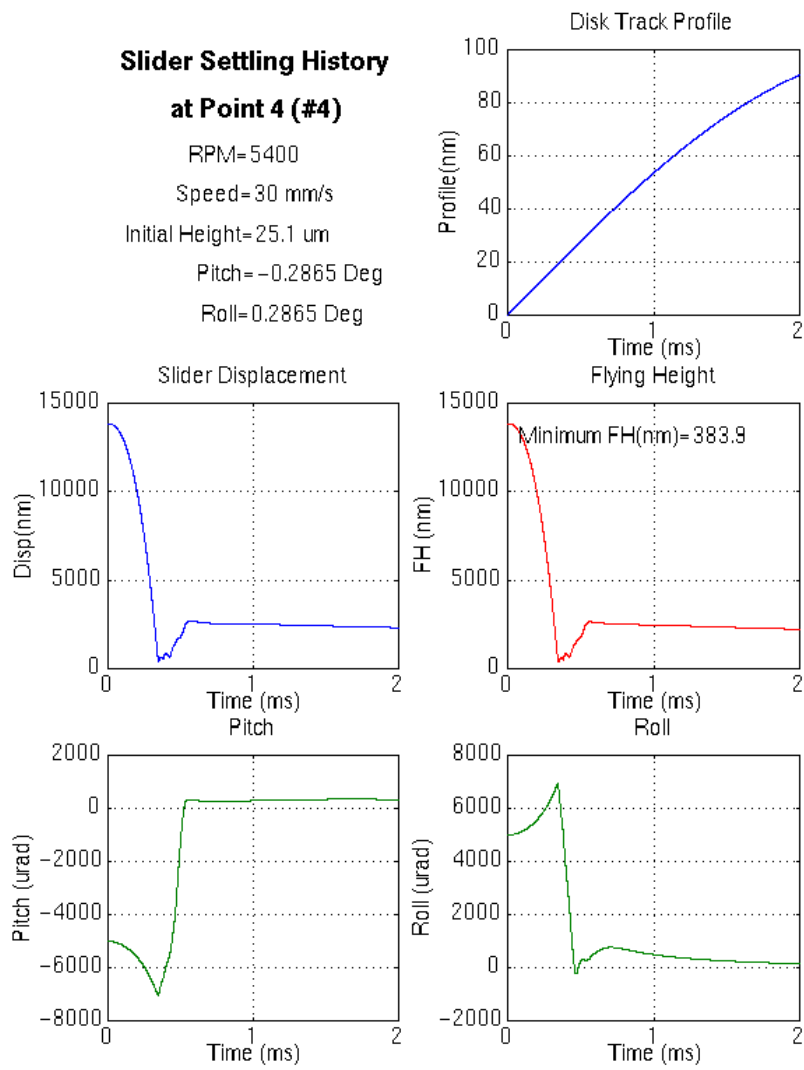


Figure 8 Flying attitude histories of the positive pressure slider during the load process with the effects of the disk run out

(Example4) created by command *flyzpr5(4,0,4000)*

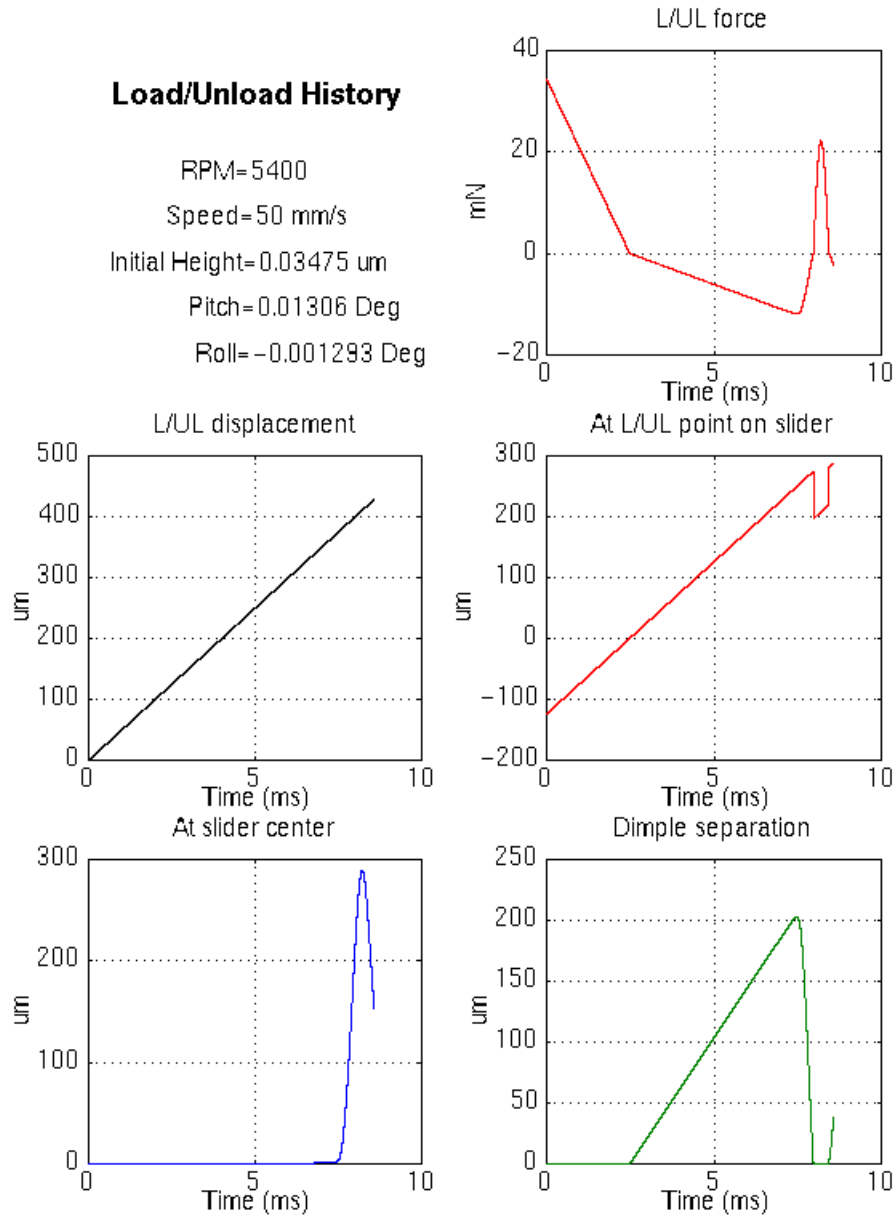


Figure 9 Force and displacement histories of the negative pressure slider during unload

(Example1) created by command *dspld5(0,0)*

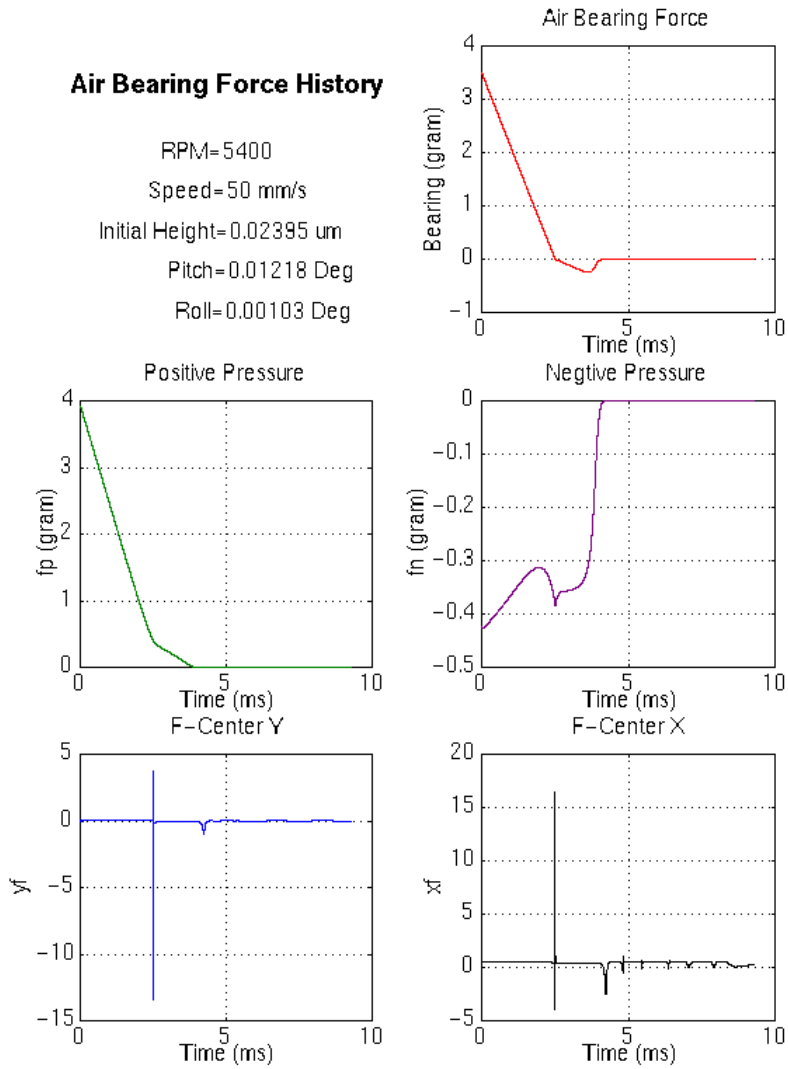


Figure 10 Air bearing force and its center positions of the positive pressure slider during unload

(Example2) created by command *force5(0,0)*

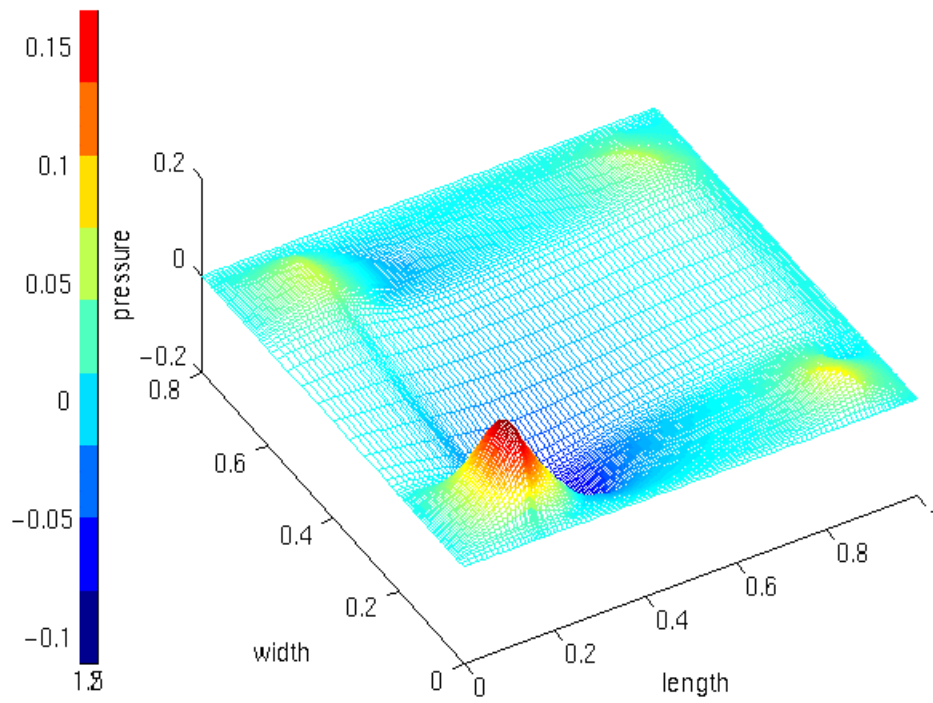


Figure 11 Air bearing pressure profile of the positive pressure slider during unload at the fourth force point (-0.15 gram)

(Example2) created by command *pressur1(4)*

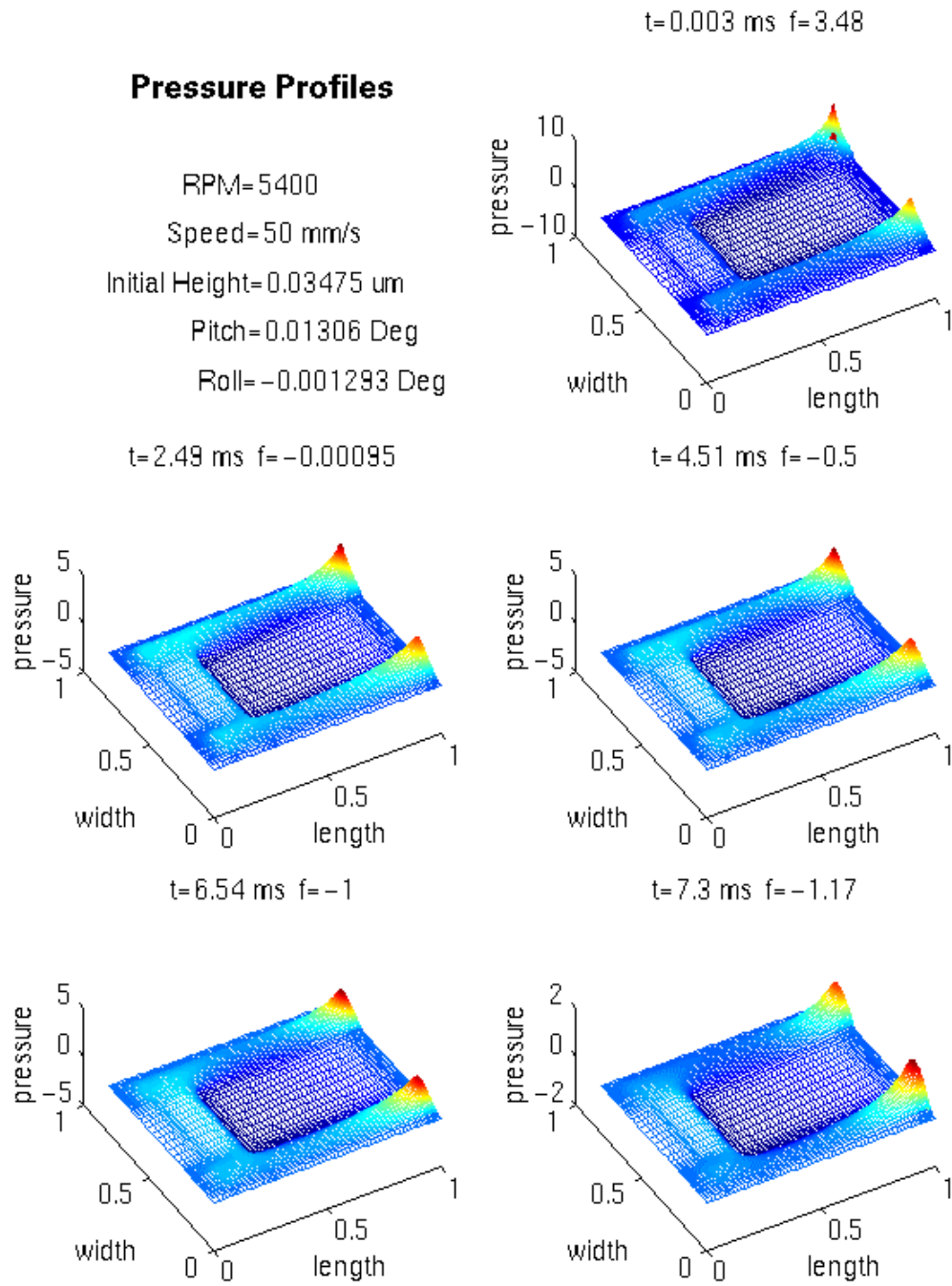


Figure 12 Air bearing pressure profiles of the negative pressure slider during unload

(Example1) created by command *pressur5*