CML Particle Flow and Slider Contamination Program User's Manual

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1. Introduction

This manual describes the first version of the CML particle flow and slider contamination program with its Matlab user interface, as well as its input files, preprocessing and post processing.

The CML particle flow and slider contamination program requires Matlab installed on the computer, a commercial software from Mathworks Inc. The CML particle flow and slider contamination program interface integrates the preprocessing and post processing with two solvers: the CML air bearing solver and the CML particle flow solver. Both solvers are written in Fortran 77 and tested under the PC/windows environment. The unix/linux operating systems are currently unsupported.

System recommendations for running the CML particle flow and slider contamination program:

Hardware:

Intel based Pentium 4 systems above 2GHz

AMD based systems above AMD 2000+

512Mb memory with 1Gb virtual memory

Software:

Windows operating systems, Windows NT, 2000, XP.

Matlab ver. 5.0 and above.

CMLAir Design Program 6.5

2. Installation

The installation package for Windows is a zipped file named **cmlparticleflow.zip**. Unpack the file into a working directory with an unzip utility such as **winzip** software. As an example, we will assume the directory is D**:\cmltemp**. When you are ready to run a simulation, copy your input files (rail.dat, run.dat, and Particles.dat) into the working directory D:**cmltemp**.

The installation does not require any association with window's core and registry system. Therefore, it is very stable and robust.

To run the software, start Matlab from the windows start menu or desktop. Then change the directory in Matlab to the current working directiory, D:\cmltemp. Enter the command, ParticleGUI in the Matlab command window. The particle flow and slider contamination program interface will show up.

3. Interface Guide

The main interface is shown in Fig. 1. The menu bar includes File, Input Files, Slider, Preprocessing, Particle Solver, Particle Flow visualization, Results and Help.

The File submenu includes one option only. You can save the current work and exit from File -> Exit.

To run the particle flow simulation, three input files are needed. They are included in the Input Files submenu as shown in Fig. 2. They are rail.dat, run.dat and Particles.dat. You can open and edit them in the notepad program provided by Windows or other commercial text editor software.

In the Slider submenu, you can verify your slider design which is imported from CMLAir Design Program. Figure 3 shows the slider submenu. You can view the 2-D rails first. After you run the CML air bearing solver, you may view its 3-D profile, pressure profile, and the spacing map between the head and disk.

Figure 4 shows the Preprocessing submenu. You can run the CML air bearing solver by clicking on “Solve Reynolds equation”. The preprocessing solver gets the necessary information for particle flow and slider contamination simulation, such as pressure and the spacing profiles where the particles will fly.

After running the CML air bearing solver, you can now run the particle solver by clicking on the “Solve particle flow” button as shown in Fig. 5. To run the particle flow, you need to make sure that Particles.dat is in the current directory. Also, to get a realistic simulation, you need to specify the particle source similar to what you expect in your experiments. The simulation will take several hours even for a modern PC, also it may take a lot of computer resources such as memory and storage spaces.

After simulating the particle flow in the head disk interface, you need to observe how the particles fly in your specific head disk interface design. The submenu “Particle Flow visualization” in Fig. 6 includes three methods of visualization. You can use the 2-D particle flow animation to see how the particles fly in HDI from a top view. You can also run the 3-D flow movie. However, this animation requires much more time and computer resources. The particle buildup history on the air bearing surface can also be visualized using the current software.

The Results submenu shown in Fig. 7 lets you see the result summary of the air bearing slider, particle contamination profile, and the contact force and moment history applied to the slider by these particles.

Figure 8 shows the Help menu. Before you run the simulation, it is recommended that you read the README file and this manual.

4. Input Data Files

There are three input data files in this version: **rail.dat, run.dat** and **Particles.dat.** The first file describes the slider geometry, while the second one prescribes the input parameters for the CML Airbearing Design Program. The third file specifies the particle properties and the environmental conditions for the particle flow simulation.

4.1 rail.dat

Sample rail.dat:

```
CML Version 4.020  RAIL.DAT
REPORT BUGS TO INFO@CML.ME.BERKELEY.EDU
1.2500E-003     1.0000E-003     3.0000E-004
 11             3
 13             1
1.1009E-003     4.1500E-004     2
1.2100E-003     4.1500E-004     0
1.2100E-003     5.8500E-004     2
```

1.1009E-003	5.8500E-004	2
9.2772E-004	5.5000E-004	2
9.0872E-004	5.4600E-004	2
8.9272E-004	5.3500E-004	2
8.8172E-004	5.1900E-004	2
8.7772E-004	5.0000E-004	2
8.8172E-004	4.8100E-004	2
8.9272E-004	4.6500E-004	2
9.0872E-004	4.5400E-004	2
9.2772E-004	4.5000E-004	2
3.0000E-007		
13	1	
1.0516E-003	5.5000E-004	3
1.0326E-003	5.4600E-004	3
1.0166E-003	5.3500E-004	3
1.0056E-003	5.1900E-004	3
1.0016E-003	5.0000E-004	3
1.0056E-003	4.8100E-004	3
1.0166E-003	4.6500E-004	3
1.0326E-003	4.5400E-004	3
1.0516E-003	4.5000E-004	3
1.2059E-003	4.1500E-004	1
1.2500E-003	4.1500E-004	0
1.2500E-003	5.8500E-004	1
1.2059E-003	5.8500E-004	3
0.0000E+000		
13	1	
4.3915E-004	7.8000E-004	2
3.3915E-004	6.7000E-004	2
3.3915E-004	5.0000E-004	0
5.0000E-005	5.0000E-004	2
5.0000E-005	7.1500E-004	2
5.3000E-005	7.4800E-004	2
6.1000E-005	7.8000E-004	2
7.4000E-005	8.1000E-004	2
9.2000E-005	8.3800E-004	2
2.0000E-004	9.6800E-004	2
6.8339E-004	9.6800E-004	0
7.0608E-004	8.4500E-004	2
6.0000E-004	7.8000E-004	2
3.0000E-007		
8	1	
6.8339E-004	9.6800E-004	1
7.6222E-004	9.6800E-004	1
7.8122E-004	9.6400E-004	1
7.9722E-004	9.5400E-004	1

```
8.0722E-004    9.3800E-004    1
8.1142E-004    9.1900E-004    1
8.1142E-004    8.7000E-004    1
7.0608E-004    8.4500E-004    3
0.0000E+000
 4             1
1.2200E-003    5.0025E-004    0
1.2200E-003    4.9975E-004    0
1.2199E-003    4.9975E-004    0
1.2199E-003    5.0025E-004    0
0.0000E+000
 12            1
6.8600E-004    4.9800E-004    0
7.5100E-004    4.9800E-004    0
7.6800E-004    5.7300E-004    0
8.4400E-004    6.1400E-004    0
9.8700E-004    7.3200E-004    0
1.2500E-003    7.3200E-004    0
1.2500E-003    9.6800E-004    0
1.0720E-003    9.6800E-004    0
1.0720E-003    8.6700E-004    0
9.7300E-004    8.1900E-004    0
7.0700E-004    6.4500E-004    0
6.8600E-004    6.4500E-004    0
1.0000E-005
 13            1
4.3915E-004    2.2000E-004    2
3.3915E-004    3.3000E-004    2
3.3915E-004    5.0000E-004    0
5.0000E-005    5.0000E-004    2
5.0000E-005    2.8500E-004    2
5.3000E-005    2.5200E-004    2
6.1000E-005    2.2000E-004    2
7.4000E-005    1.9000E-004    2
9.2000E-005    1.6200E-004    2
2.0000E-004    3.2000E-005    2
6.8339E-004    3.2000E-005    0
7.0608E-004    1.5500E-004    2
6.0000E-004    2.2000E-004    2
3.0000E-007
 8             1
6.8339E-004    3.2000E-005    1
8.6222E-004    3.2000E-005    1
8.8122E-004    3.6000E-005    1
8.9722E-004    4.6000E-005    1
9.0722E-004    6.2000E-005    1
```

9.1142E-004 8.1000E-005 1
9.1142E-004 1.3000E-004 1
7.0608E-004 1.5500E-004 3
0.0000E+000
4 1
1.1340E-003 9.6800E-004 0
1.1340E-003 8.6700E-004 0
1.2500E-003 8.6700E-004 0
1.2500E-003 9.6800E-004 0
0.0000E+000
12 1
8.0000E-005 4.2000E-004 3
8.0000E-005 2.8500E-004 3
8.3000E-005 2.5200E-004 3
9.1000E-005 2.2000E-004 3
1.0400E-004 1.9000E-004 3
1.2200E-004 1.6200E-004 3
2.3000E-004 5.2000E-005 1
4.1694E-004 5.2000E-005 3
4.1694E-004 1.6000E-004 3
3.5915E-004 1.6000E-004 3
2.4915E-004 3.0000E-004 3
2.4915E-004 4.2000E-004 3
0.0000E+000
12 1
8.0000E-005 5.8000E-004 3
8.0000E-005 7.1500E-004 3
8.3000E-005 7.4800E-004 3
9.1000E-005 7.8000E-004 3
1.0400E-004 8.1000E-004 3
1.2200E-004 8.3800E-004 3
2.3000E-004 9.4800E-004 1
4.1694E-004 9.4800E-004 3
4.1694E-004 8.4000E-004 3
3.5915E-004 8.4000E-004 3
2.4915E-004 7.0000E-004 3
2.4915E-004 5.8000E-004 3
0.0000E+000
10 10 10
0.0000E+000 1.3822E-006 2.7644E-006 4.1467E-006 5.5289E-006 6.9111E-006
8.2933E-006 9.6756E-006 1.1058E-005 1.2440E-005
0.0000E+000 5.2469E-007 9.8765E-007 1.3889E-006 1.7284E-006 2.0062E-006
2.2222E-006 2.3765E-006 2.4691E-006 2.5000E-006
0.0000E+000 1.2222E-006 2.4444E-006 3.6667E-006 4.8889E-006 6.1111E-006
7.3333E-006 8.5556E-006 9.7778E-006 1.1000E-005

```
 3.0000E-007  7.6173E-007  1.1691E-006  1.5222E-006  1.8210E-006  2.0654E-006
2.2556E-006  2.3914E-006  2.4728E-006  2.5000E-006
 0.0000E+000  1.6933E-007  3.3867E-007  5.0800E-007  6.7733E-007  8.4667E-007
1.0160E-006  1.1853E-006  1.3547E-006  1.5240E-006
 0.0000E+000  6.2963E-008  1.1852E-007  1.6667E-007  2.0741E-007  2.4074E-007
2.6667E-007  2.8519E-007  2.9630E-007  3.0000E-007
0.0000E+000     0.0000E+000     2.5000E-006
2.5400E-008     2.5000E-009     0.0000E+000
 1.2200E-003  1.2050E-003  2.4100E-004  2.4100E-004
 5.0000E-004  5.0000E-004  9.7400E-004  2.6000E-005
```

The rail structure for this sample file is shown in Fig. 9. The first two lines are the header. The third line contains the slider dimensions in meters: **length**, **width**, **thickness**. The fourth line indicates the **number of rails** and the **number of (different) wall profiles** used. Next, each rail is defined in succession. The starting line for each rail describes the **number of points** and **style**. A **step** has a **style** value of 1, while a **ramp** has a **style** value of 0. The lines that follow contain the **x and y coordinates** of a rail point and the **wall profile index** for the rail edge starting at that point. Note that the **x and y coordinates** are in meters instead of normalized, and the **wall profile indices** should be zero for a **ramp**. The final line in a rail description contains the **recess height(or three heights** for a **ramp)** in meters for the rail. The line that follows the rail definitions contains **the number of wall profile points** for all wall profiles. Next, each wall profile definition occupies two lines. The first line contains the normal distances to the nominal edge for the profile points. Note, the unit is in meters. A negative value indicates that the point is inside the nominal rail boundary, while a positive value is otherwise. The second line contains the recess depth in meters for each point. Note that the zero recess reference plane is the same as for all the rail recess depths, rather than the nominal recess for each rail. The next line contains the **taper length** in meters, the **taper**

angle in radians, and the **base recess** in meters. The following line gives the crown, camber and twist in meters. The final two lines are the **x and y coordinates** for the points of interest.

4.2 run.dat

Sample run.dat:

```
CML Version 6.020  RUN.DAT
REPORT BUGS TO INFO@CML.ME.BERKELEY.EDU
***************Solution Control***************
istiff isolv   ioldg   iadpt   isave
 1      1       0       1       1
***************Intial Attitude***************
hm(m)          pitch(rad)     roll(rad)
1.0000E-008    1.5000E-004    0.0000E+000
***************Runs***************
irad           irpm           ialt
 1             1              0
radii(m)
   2.3000E-002
skews(deg)
   9.1000E+000
RPMs
   7.2000E+003
altitudes(m)

***************Air Parameters***************
p0(pa)         al(m)          vis(nsm^-2)
1.0135E+005    6.3500E-008    1.8060E-005
***************Load Parameters***************
f0(kg)         xf0(m)         yf0(m)
1.5000E-003    0.0000E+000    0.0000E+000
xfs(µNM)       yfs(µNM)       emax
0.0000E+000    0.0000E+000    1.0000E-003
***************Grid Control***************
nx      ny
 593     593
nsx      nsy     isymm
 1       1       0
xnt(i), i = 2, nsx
```

```
nxt(i), i = 2, nsx

dxr(i), i = 1, nsx
 1
ynt(i), i = 2, nsy

nyt(i), i = 2, nsy

dyr(i), i = 1, nsy
 1
***************Adaptive Grid***************
difmax      decay      ipmax
 100        60         1
 100        60           0
****************Mesh refinement in x direction*******
1
0.380e-3   0.42e-3    0
****************mesh refinement in y direction*******
1
0.325e-3   0.375e-3   0
***************Reynolds Equation***************
ischeme      imdoel      akmax      beta       gamma      accommodation
 2           3           1.0000E-007   6.0000E+000   6.0000E+000   1.0000E+000
***************Partial Contact***************
icmodel      stdasp(m)     dnsasp(m^-2)   ConstantA     ConstantB
 0           0.0000E+000   1.0000E+012   1.0000E-019   1.0000E-076
rdsasp(m)      eyoung(pa)     yldstr(pa)
0.0000E+000   1.0000E+010   1.0000E+012
frcoe        pratio
 0.3         0.3
***************Molecular Force Hamaker Constants(ahc,bhc)*****
0.0e-19      0.0e-76
***************Sensitivities***************
crowninc(m)    camberinc(m)   twistinc(m)
0.0000E+000   0.0000E+000   0.0000E+000
tlnginc(m)     tanginc(rad)   loadinc(kg)
0.0000E+000   0.0000E+000   0.0000E+000
ptrqinc(μNM)   rtrquinc(μNM)  recessinc(m)
0.0000E+000   0.0000E+000   0.0000E+000
iwscale
 1
***************Comments***************
"This is a test case"
```

Here are some explanations:

Solution Control:

istiff: 1 = calculate stiffness, 0 = no stiffness calculation

isolv: 1 = solve for fly height, 0 = given attitude

ioldg: 1 = use existing grid data, 0 = create new grid

iadpt: 1 = use adaptive grid, 0 = no adaptive grid

isave: 1 = save pressure and mass flow, 0 = don't save

Initial Attitude:

hm(m): nominal trailing edge height

pitch(rad): pitch, note the change in units from the previous version

roll(rad): roll

Runs:

irad: number of disk radii where the solution is sought

irpm: number of RPMs

ialt: number of altitudes, 0 = use Air Parameters

radii(m): disk radii

skews(deg): skews corresponding to each disk radii

rpms: RPMs

altitudes(m): altitudes, lowest one is the base case.

Air Parameters:

p0(pa): ambient pressure

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al(m): mean free path

vis(NS/M_2): viscosity

Load Parameters:

f0(kg): load

xf0(m): load point x offset, origin is at the geometric center now!

yf0(m): load point y offset

xfs(μNM): static pitch torque, note the change of unit

yfs(μNM): static roll torque

emax: convergence criterion of load error

Grid Control:

nx: total x grid number (16k+1)

ny: total y grid number (16k+1)

nsx: number of sections in length

nsy: number of sections in width

isymm: 1 = symmetry in width, 0 = specify entire width

xnt(i), i = 2, **nsx**: x control points in meters, no longer normalized!

nxt(i), i = 2, **nsx**: grid indices at x control points

dxr(i), i = 1, **nsx**: grid ratios for each x section

ynt(i), i = 2, **nsy**: y control points, use half width if **isymm** = 1

nyt(i), i = 2, **nsy**: grid indices at y control points

dyr(i), i = 1, **nsy**: grid ratios for each y section

Adaptive Grid:

difmax: ratio of max/min gradient allowed

decay: smaller value increases smoothness

ipmax:1 = use maximum gradient, 0 = average gradient

The adaptive grids in the x and y directions are controlled separately by two lines. The first line specifies difmax, decay and ipmax for the x direction. The second line defines these parameters for the y direction.

Mesh refinement in x and y directions:

The first line defines how many locations will be refined by the end user. The following lines specify the starting and ending locations for mesh refinement.

Reynolds Equation:

ischeme: convective term scheme.

0 = upwind

1 = hybrid

2 = power-law; default

imodel: slip model

1 = first order slip

2 = second order slip

3 = FK; default

akmax: convergence criterion for the Reynolds equation

Partial Contact:

icmodel: 0 = no contact model

1 = Greenwood-Williamson

2 = Elastic-Plastic

stdasp(m): standard deviation of asperity height

dnsasp(m^{-2}): asperity density

rdsasp(m): mean radius of curvature of asperity

eyoung(pa): Young's modulus

yldstr(pa): yield strength

frcoe: friction coefficient

pratio: Poisson's ratio

Intermolecular Force menu

Two constants, **ahc** and **bhc**, are defined for the adhesive force between the head and disk for ultra low flying height sliders. The first one is the effective Hamaker constant between the slider and disk. The second is the constant B used in the Lernard Jones potential. For detailed information of these two parameters, please refer to Lin Wu's Ph. D. dissertation at CML, "Physical Modeling and Numerical Simulations of the Slider Air Bearing Problem of Hard Disk Drives".

Sensitivities:

Zero increment means no sensitivity is calculated for the parameter.

crowninc(m): crown increment

camberinc(m): camber increment

twistinc(m): twist increment

tlnginc(m): taper length increment

tanginc(rad): taper angle increment

loadinc(kg): load increment

ptrqinc(μNM): pitch torque increment

rtrqinc(μNM): roll torque increment

recessinc(m): recess increment

iwscale: used with **recessinc**

0 = stretch the profile, the normal distances are unchanged,

only the depths are scaled.

1 = scale the wall profile with recess. For the part of the

profile that is outside the nominal rail boundary, the normal

distances will change proportionally with recess.

4.3 Particles.dat

Sample Particles.dat

```
lamda      rous      roup       amu          p0
.635e-7  1.4128d0   3.52d3   1.488e-5   1.0135e+5
NX|NY|NZ|
1   50  10
Xmean Std
200e-09 50e-9
  xp0      yp0       zp0
 0.02       0.04         6.0
 0.02       0.75        25.0
The velocity ratio to the disk |particle velocity option
7.5 2
 Time for simulation (T, DT)
5.0  1e-3
|The skew angle of the slider| Particle Module|Particle Distribution Option|
-17.55 2 2
|Gravity Effect| Saffman Lift|Magnus Lift | Pressure Gradient|Vortex
0.0 1.0 1.0 1.0 1.0
|Particle|Airbearing Module|Layer Streamline Module|
1 0 0
|Particle Nature:1: Soft; 2: Hard|
2
|Mechanical and Thermal Properties of particle(TiC)|
Young's Modulus|Poison's Raio|Hardness|Thermal conductivity|SPecific Heat|
4.39d11    0.187          2.47d9              30.9                710.6
Disk Material Properties(Aluminum)
|Density|Modulus|Poison's Ratio|Hardness|Thermal Conductivity|Specfific Heat(J/kg.C)|
2.7d3      6.9d10      0.3269      1.20d8           166.9          896
Slider Material Properties(TiC 40% Al2O3 60%)
|Density|Modulus|Poison's Ratio|Hardness|Thermal Conductivity|Specfific Heat|
4.31d3     4.390d11      0.2          2.42e9              27.0          898
Friction Coefficient( Betweeen particle and slider)
0.2
```

lamda: free mean path of the air.

rous: air density

roup: particle density

amu: air viscosity.

p0: air ambient pressure.

NX,NY,NZ: Number of particles in the X, Y, Z directions.

Xmean, Std (m): these two parameters define the particle mean size and standard deviation for a Gaussian distribution.

xp0, yp0, zp0: define the initial location of the particles. The first line defines the lowest value of x, y, z. The second line defines the upper limit of x, y, z.

The velocity ratio of particle to the disk is used for the initial particle velocity option. Particle velocity option: 1: its ratio to the disk velocity is specified. 2: air borne particles. 2 is the default option for most cases.

T, DT: simulation time and time step. These two are normalized. The user can change the time step to balance the calculation time and accuracy based on experience.

In the remaining part of the input file, each item is clearly defined. The user can enter the corresponding value for specific case.

5. Output data files

The output files include ParticleD.dat, Pcontaminates.dat, Summary.dat, and Contacts.dat. These output files are post processed in the particle flow and slider contamination software interface.

6. Post processing

The post processing for particle flow and slider contamination includes visualization of the particle flow in the head disk interface, the final particle contamination profile on the slider, and the contact force and moment history acting on the air bearing slider. They are integrated into the software interface. Advanced users may modify the corresponding module to get other information. For visualization post processing, a movie file is generated for each animation. They are found in your working directory after you run the animation.

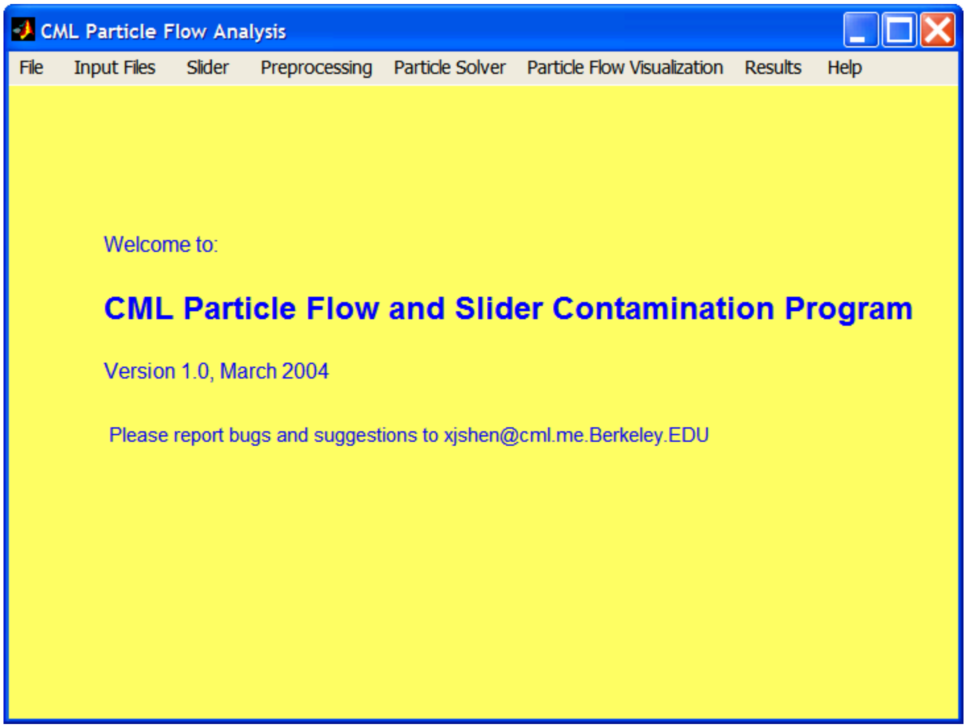

Figure 1. Matlab Interface

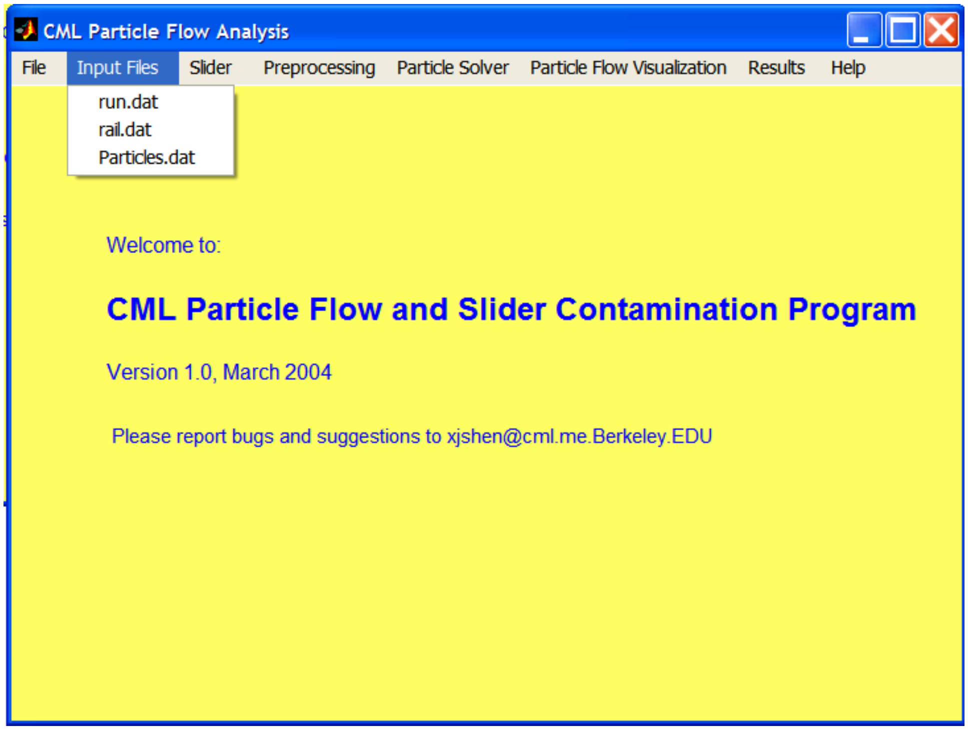

Figure 2. Input Files

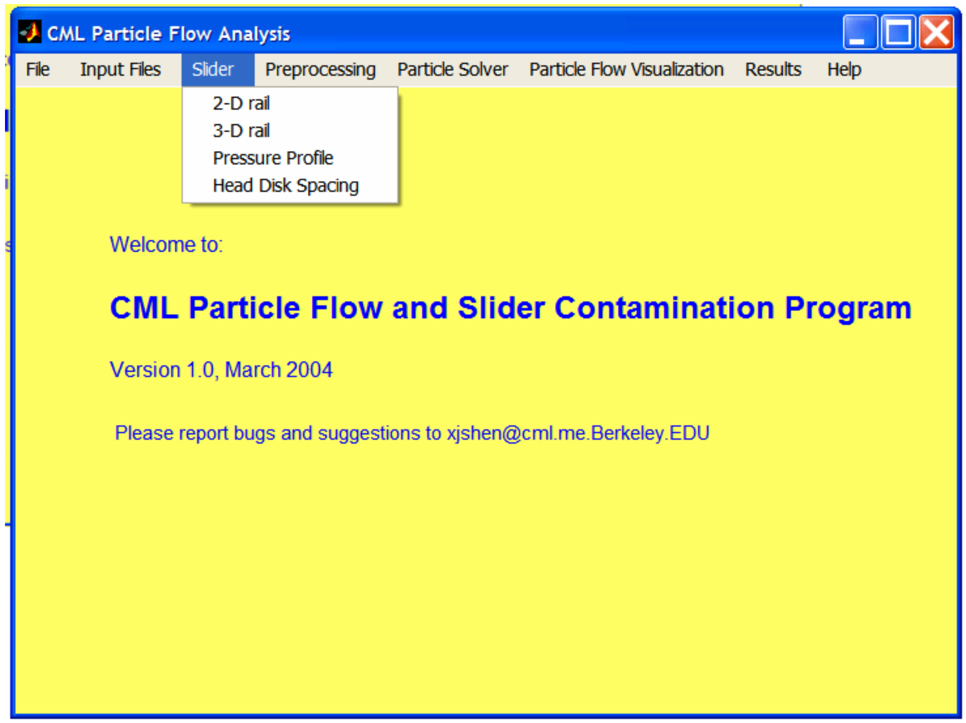

Figure 3. Slider Information

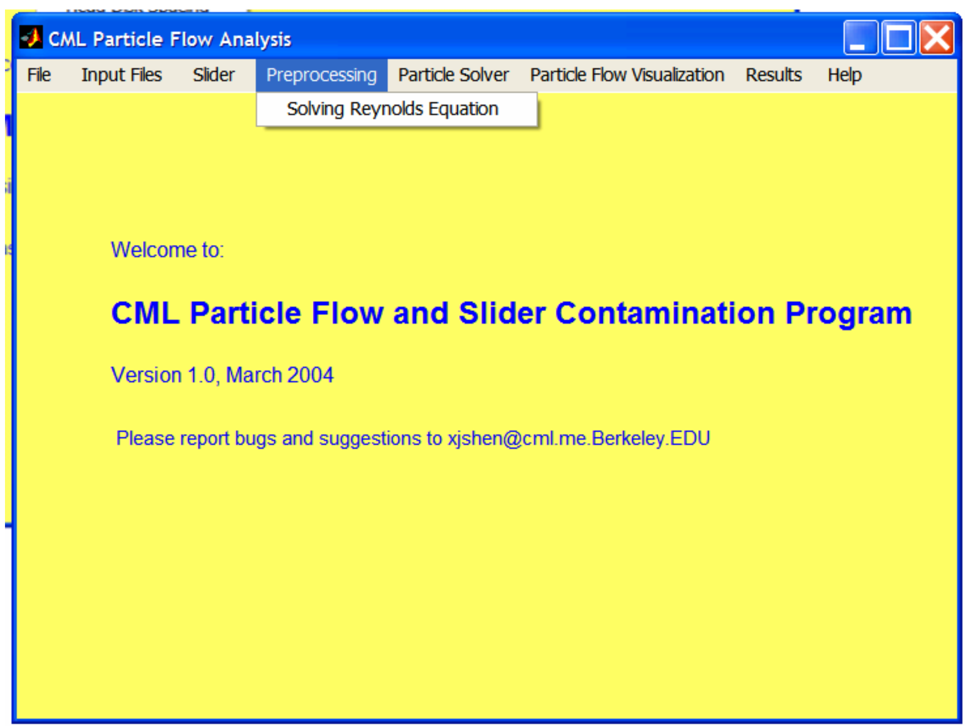

Figure 4. CML Air Bearing Solver

Figure 5. CML Particle Flow and Slider Contamination Solver

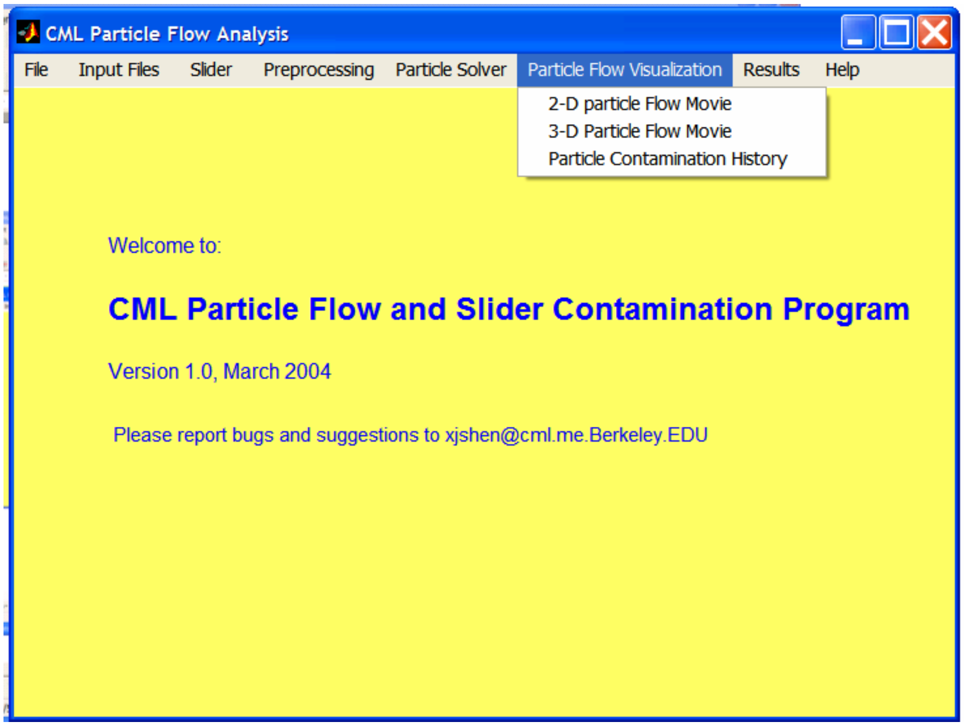

Figure 6. Particle Flow Visualization Modules

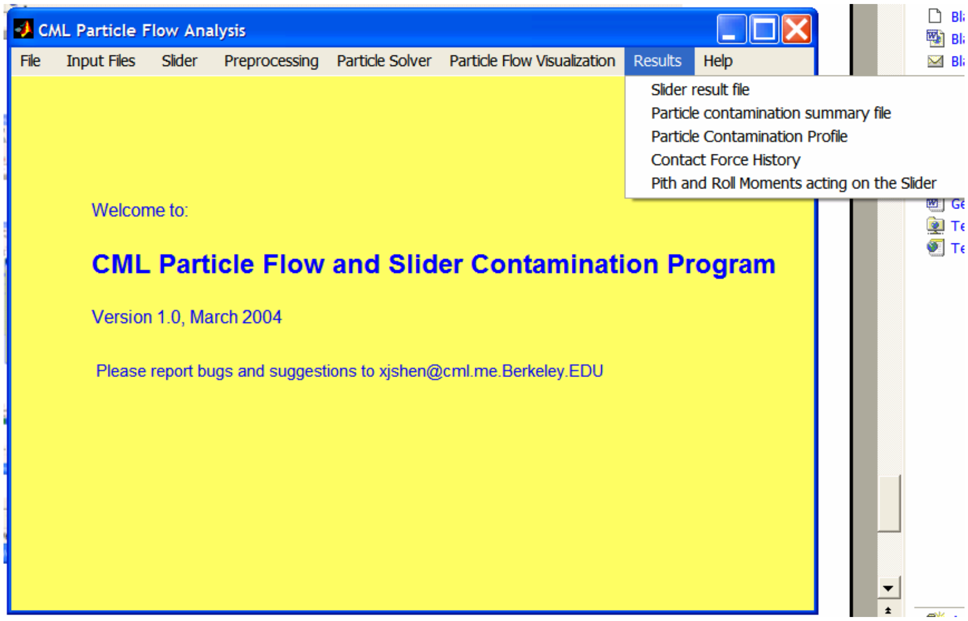

Figure 7. Particle Result Files

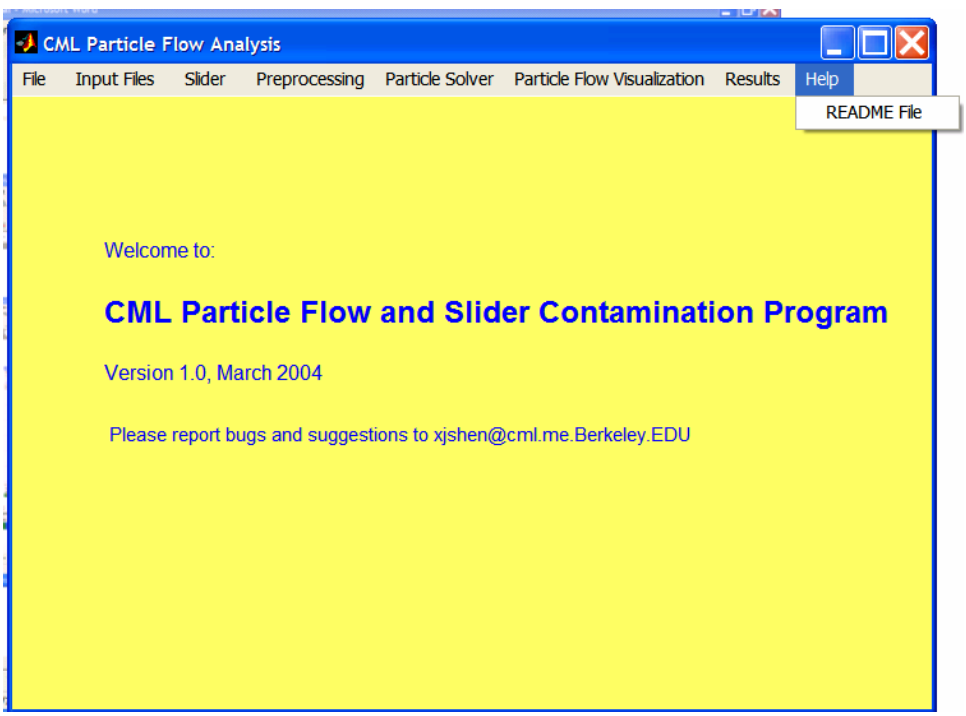

Figure 8. User's Manual and README Files

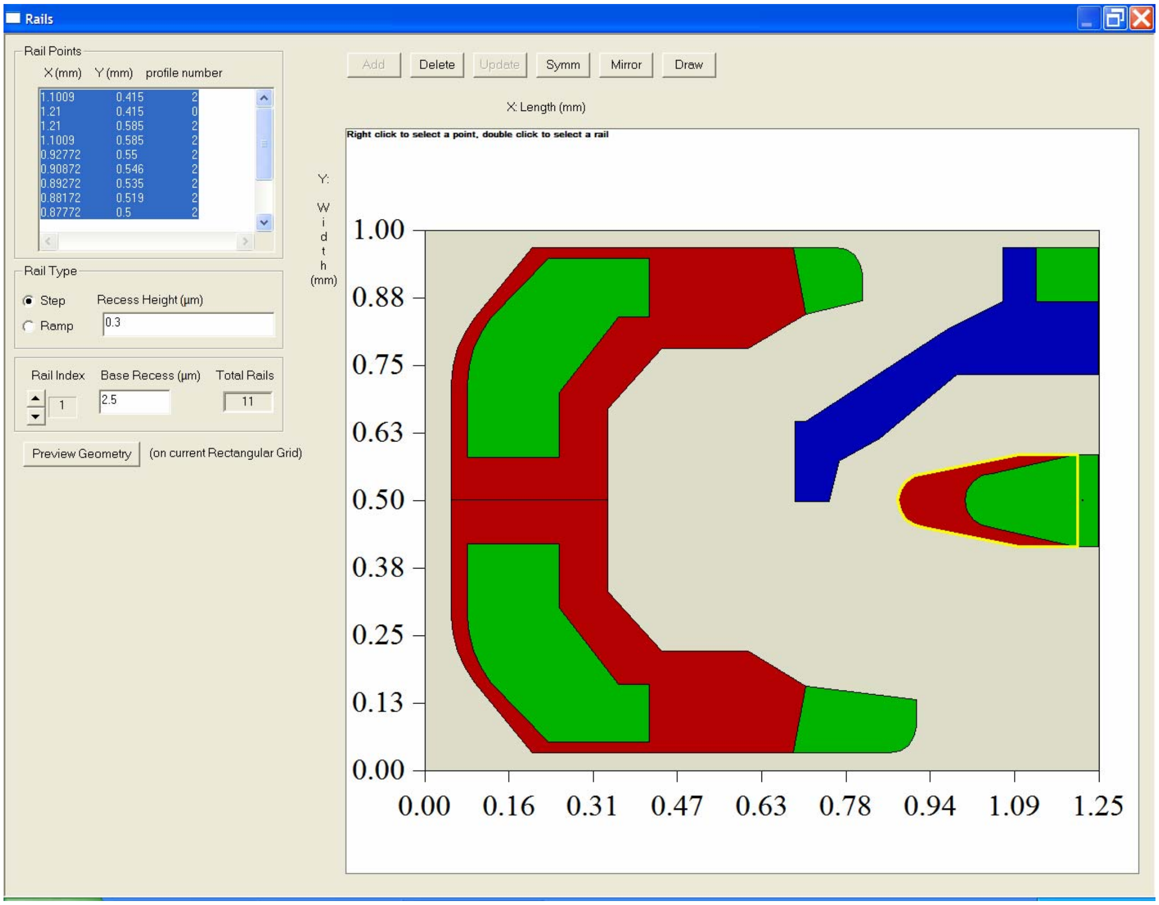

Figure 9. A sample air bearing slider.