CML Lubricant Thickness Code User's Manual

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1 Introduction

The CML Lubricant Thickness Code is used to calculate the film thickness on the air bearing surface (ABS) of a slider as a function of time. The evolution of the film, as depicted in Fig. 1, is driven by the air shear stress, air bearing pressure and disjoining pressure. The slider ABS must be coated initially by an arbitrary (user defined) distribution of lubricant. The code solves numerically a partial differential equation (PDE) that governs the film thickness evolution [1]. The governing PDE is obtained from classical lubrication theory and is discretized using a second order accurate finite difference scheme.

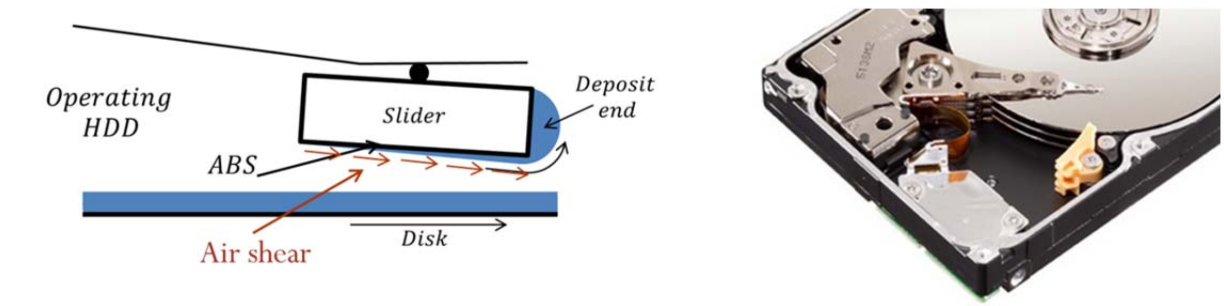

Fig. 1. Schematic representation of lubricant migration on the slider surface.

The governing equation solved is given by,

$$h_t + \nabla \cdot \left\{ \frac{h^2}{2\mu} \boldsymbol{\tau} + \frac{h^3}{3\mu} \nabla [\Pi(h) - p] \right\} = 0, \qquad (1)$$

where $h, \mu, \Pi(h), p, \boldsymbol{\tau} = (\tau_x, \tau_y)$ are the film thickness on the slider's ABS, lubricant viscosity, film disjoining pressure, air pressure and air shear stress respectively. The sub index t in the first term represents a time partial derivative. Also $\nabla \cdot, \nabla$ are the two dimensional divergence and gradient operators with respect to the x and y coordinates as shown in Fig. 2. The film disjoining pressure considered here is only determined by van der Waals forces so that

$$\Pi(h) = \frac{A}{6\pi} h^{-3}, \qquad (2)$$

where A is known as the Hamaker constant.

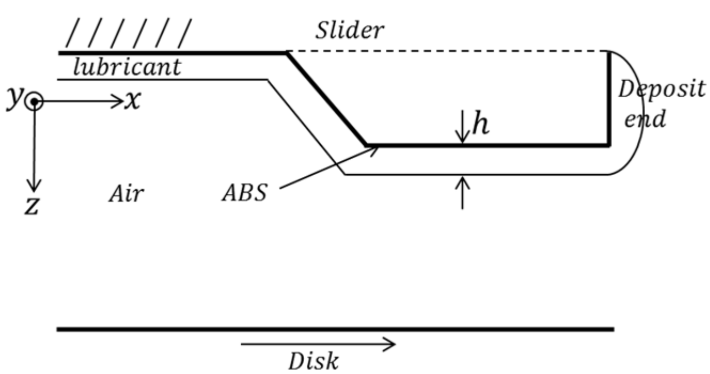

Fig. 2. Slider coated with a liquid film flying over a moving disk.

2 Input files

The CML Lubricant Thickness Code requires the following input files: *Run_Lube.dat, CShearX01.dat, CShearY01.dat, PShearX01.dat, PShearY01.dat, press01.dat* and *hinit.dat*. The last of these files is optional, it is only required when the initial condition consists of a non-uniform film thickness on the ABS. The input files *CShearX01.dat, CShearY01.dat, PShearX01.dat, PShearY01.dat, press01.dat* can be taken from the output files obtained after running a case in the CMLAir air bearing code [2] using a uniformly spaced grid. A sample of the *Run_Lube.dat* file is shown in Fig 3.

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******* CML Lubricant Thickness Code ******
Hamaker constant A (J)
1e-18
Initial condition: uniform (0) or user defined (1)
0
Initial uniform thickness (nm)
1.0
Lubricant viscosity (Pa*s)
1
Final time (s),     Time step (s)
4                      0.01
ABS length (m),      ABS width (m)
0.85e-3                 0.7e-3
Grid Size (must use same values as press01)
nx      ny
209     209
Slider lateral walls (# of extra nodes on LE, TE, ID, OD)
nLE     nTE     nID     nOD
3       10      3       3
Output solution every (s):
4
```

Fig. 3. Sample *Run_Lube.dat* file

The file *Run_Lube.dat* must contain the following information:

- In **line 3** the user must enter the value of the Hamaker constant A that specifies the disjoining pressure given by equation (2). The value of A must be in Joules.
- In **line 5** the user must enter either 0 if the initial lubricant distribution on the ABS is uniform, i.e. the film thickness is initially constant on the entire slider surface, or 1 if the lubricant thickness is not uniform on the entire ABS. When option 1 is specified, the user must include the input file *hinit.dat* which contains the values of the film thickness at each grid point on the slider surface arranged as a matrix. The matrix must have the same dimensions (nLE+nx+nTE) by (nID+ny+nOD) as the output files described below.
- In **line 7** the user must enter the value of the initial uniform film thickness which corresponds to option 0 of **line 5**.
- In **line 9** the user must enter the value of the lubricant viscosity.
- In **line 11** the user must enter the final (total) time of the numerical simulation and the time step of each numerical iteration.
- In **line 13** the user must enter the length and width of the slider's ABS.
- In **line 16** the user must enter the number of grid points nx, ny along the length and width of the ABS respectively. The values of nx, ny must correspond to the number of columns and rows in *press01.dat* respectively.

- In **line 19** the user must enter the desired number of grid points nLE, nTE, nID, nOD along the Leading Edge, Trailing Edge, Inner Diameter and Outer Diameter vertical walls of the slider respectively. Here, we consider that the four lateral walls of the slider can be unfolded placing them on the same plane with the ABS as depicted in Fig. 4. The reason for allowing this condition is to study the lubricant accumulation outside the ABS using the two-dimensional model given by equation (1). The values of nLE, nTE, nID, nOD can all be zero if desired.
- In **line 21** the user must enter the desired frequency at which the solution is to be output.

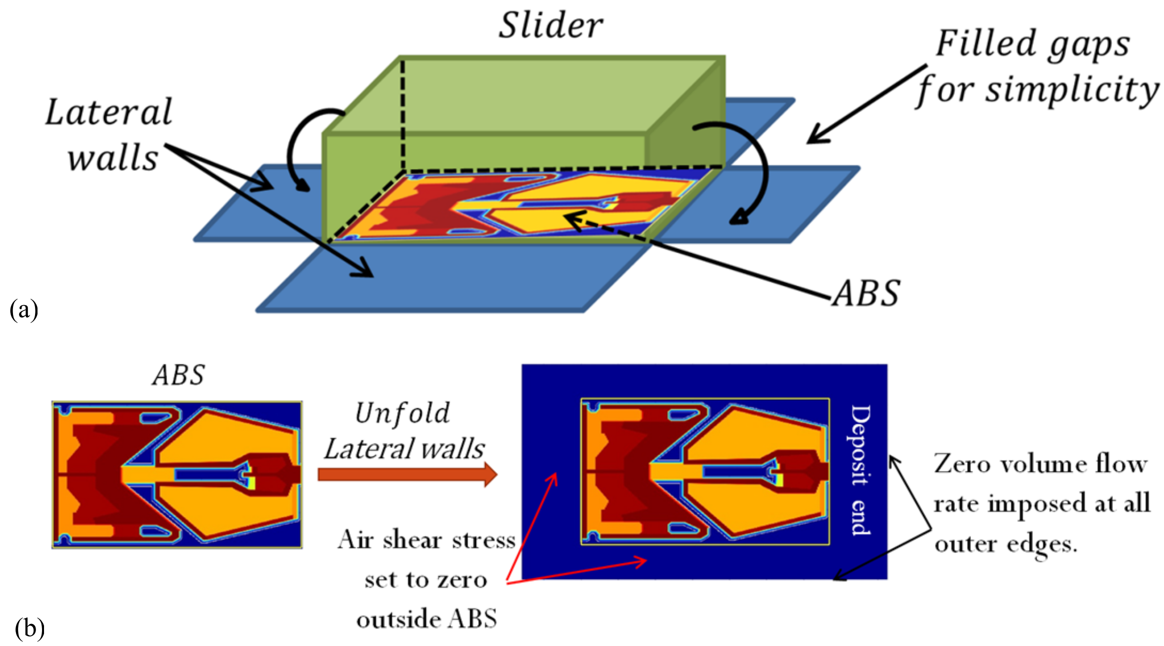

Fig. 4. (a) Slider lateral walls unfolded, (b) Boundary conditions imposed on the unfolded lateral walls.

The output files *hLXXXXs.dat* contains the values of the lubricant film thickness in nm at each grid point. These output files can be used as the initial condition *hinit.dat* for other subsequent simulations if desired.

1 References

[1] Mendez, A. R., Bogy, D. B. (2014). Lubricant flow and accumulation on the slider's air-bearing surface in a hard disk drive. Tribology Letters, 53(2), 469-476.
[2] http://cml.berkeley.edu/cmlair_new.html