

Using PROPID for Analysis

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Steady-State Aerodynamics Codes for HAWTs
Selig, Tangler, and Giguère



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National Renewable Energy Laboratory



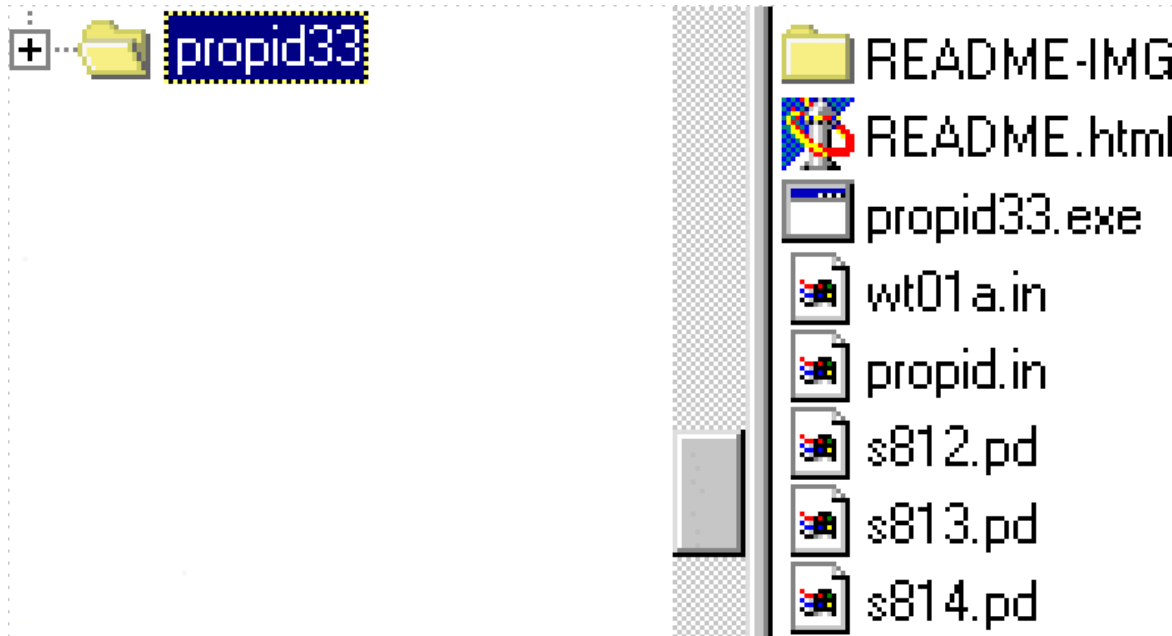
PROPID Code / Files Overview

- PROPID Code:
 - Fortran77
 - 14,000 lines
- Files
 - propid53-32bit - DOS executable, latest version
 - propid.in - includes the input file name to run
 - wt01a.in - PROPID input file to run
 - s818.pd, etc - airfoil data files
 - ftn040.dat, etc - output files generated
- File Organization
 - Keep all files in the same directory (for simplicity)



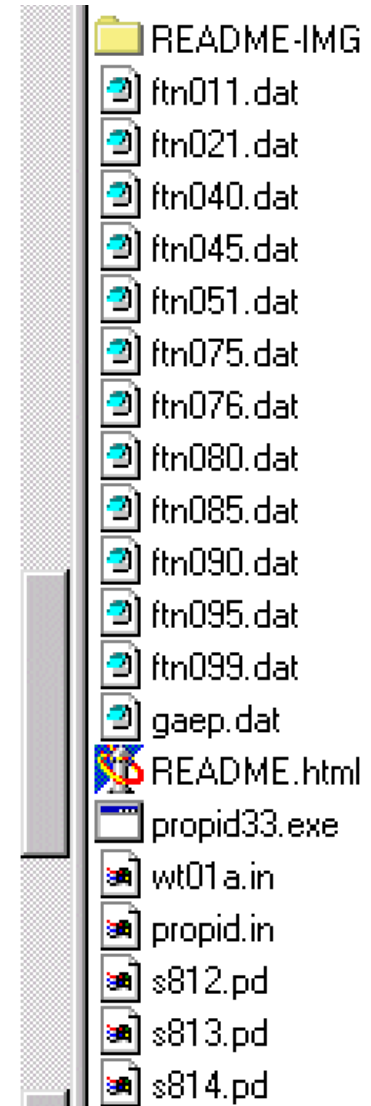
Getting Started

- Installation - PROPID
 - Copy the propid33.zip file (or latest version) to your PC and unzip to get:

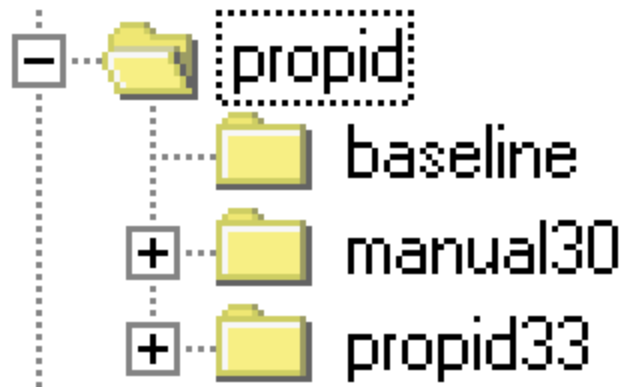


– To run, open a DOS window and type
propid33.exe

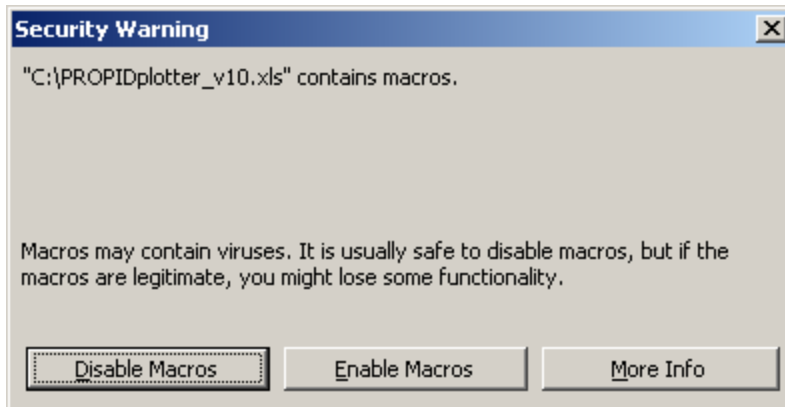
- Directory structure with output files



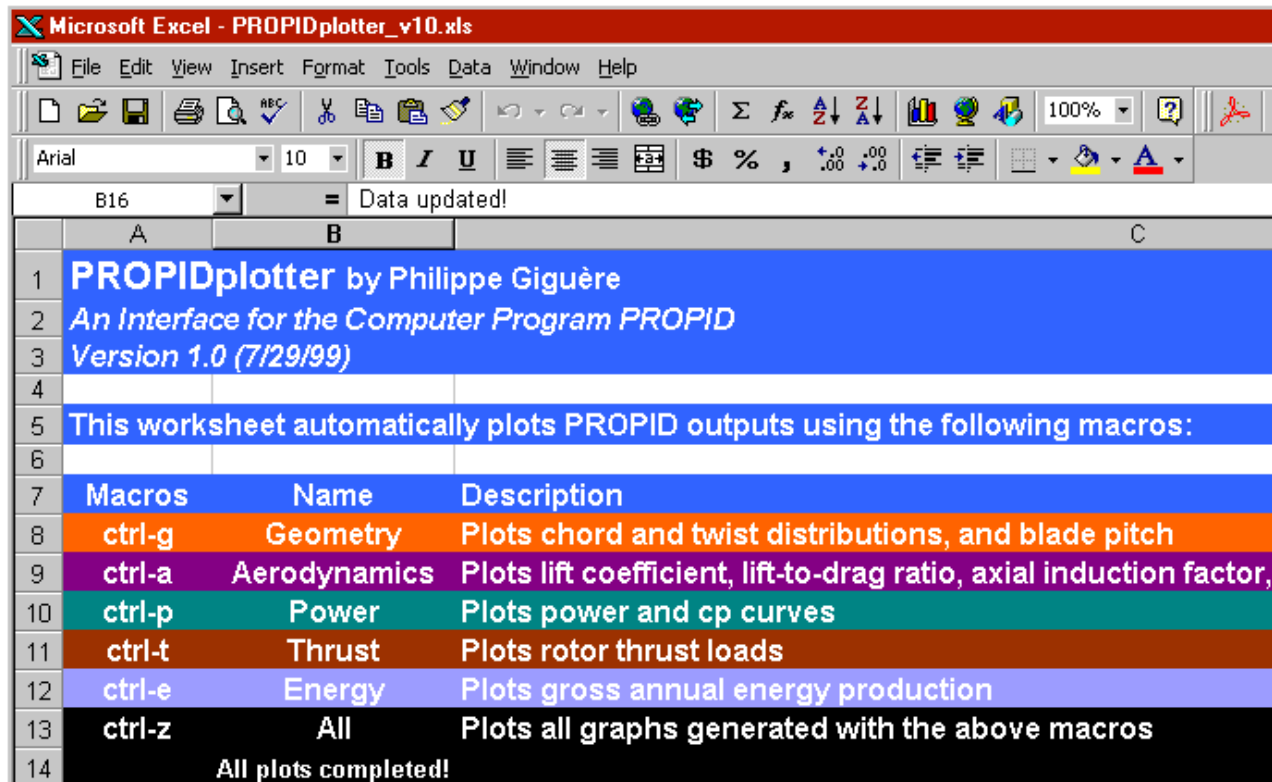
- Additional directories
 - baseline dir - files for comparison
 - manual30 - propid30 manual



- Installation - PROPIDplotter_v10.xls
 - Put PROPIDplotter_v10.xls in the “propid33” directory, which is ”“working” directory
 - Click on file. If prompted, click on “Enable Macros” (see below). Macros will be enabled only during the current session on the current file.



- PROPID Run: wt01a.in
 - ✓ Edit propid.in to include the filename wt01a.in
 - Type propid33.exe to run (or latest version)
 - Plot the data using PROPIDplotter (ctrl-z)



The screenshot shows a Microsoft Excel window titled "Microsoft Excel - PROPIDplotter_v10.xls". The spreadsheet contains the following text:

PROPIDplotter by Philippe Giguère
An Interface for the Computer Program PROPID
 Version 1.0 (7/29/99)

This worksheet automatically plots PROPID outputs using the following macros:

Macros	Name	Description
ctrl-g	Geometry	Plots chord and twist distributions, and blade pitch
ctrl-a	Aerodynamics	Plots lift coefficient, lift-to-drag ratio, axial induction factor,
ctrl-p	Power	Plots power and cp curves
ctrl-t	Thrust	Plots rotor thrust loads
ctrl-e	Energy	Plots gross annual energy production
ctrl-z	All	Plots all graphs generated with the above macros

All plots completed!



Documentation Sources

- Web based documentation at
 - <http://www.ae.illinois.edu/m-selig/propid/>
- The most current documentation for reference
 - propid-doc.txt
- Quick reference
 - propid-quickRef.txt
- wt-series input file descriptions
 - 00-wt-series.txt



Program Flow Control

- Uses a keyword journal-command structure
 - Screen grab from the manual: propid-doc.txt

Keyword → `<TIPMODE>`

Value → `<JDPRMP>`

Comment → `# specify tolerance for auto-iteration mode for NEWT1`

```
emacs@amber.aae.uiuc.edu
Buffers Files Tools Edit Search Makefile Help
>>line> TIPMODE <TIPMODE> # 1 is the default and it the Prandtl-Wilson model
# 2 is the Prandtl model alone (added 981011)
>>line> TIPSPEED <JDPRMP> # give the tip speed in ft/sec for the given RPM d
# this calculation does not include the wind speed
>>line> TIPON # forces the tip loss model to be on always
# (even when past the stall
# angle when otherwise it would be turned off---see prop.f)
# It is suggested that this always be on
>>line> TOLSP1 <TOLSP1> # specify tolerance for auto-iteration mode for NEWT1
>>line> TOLSP2 <TOLSP2> # specify tolerance for auto-iteration mode for NEWT2
>>line> TAPERED_TIP <taptip> # used for pultruded blade design with a tapered
# tip. This feature only scales the last blade
# chord by taptip, eg taptip = .90 shortens
# the tip chord by 10%.
# Line acts as a logical toggle (on/off).
# PROPID notes 3-9-98 p 1
>>line> REFIX <REFIX> # Fixes Re for all analysis
# REFIX is fixed Reynolds number to use
-----Emacs: propid-doc.txt 11:52am 0.04 Mail (Makefile Font)--L691--C0--3
```

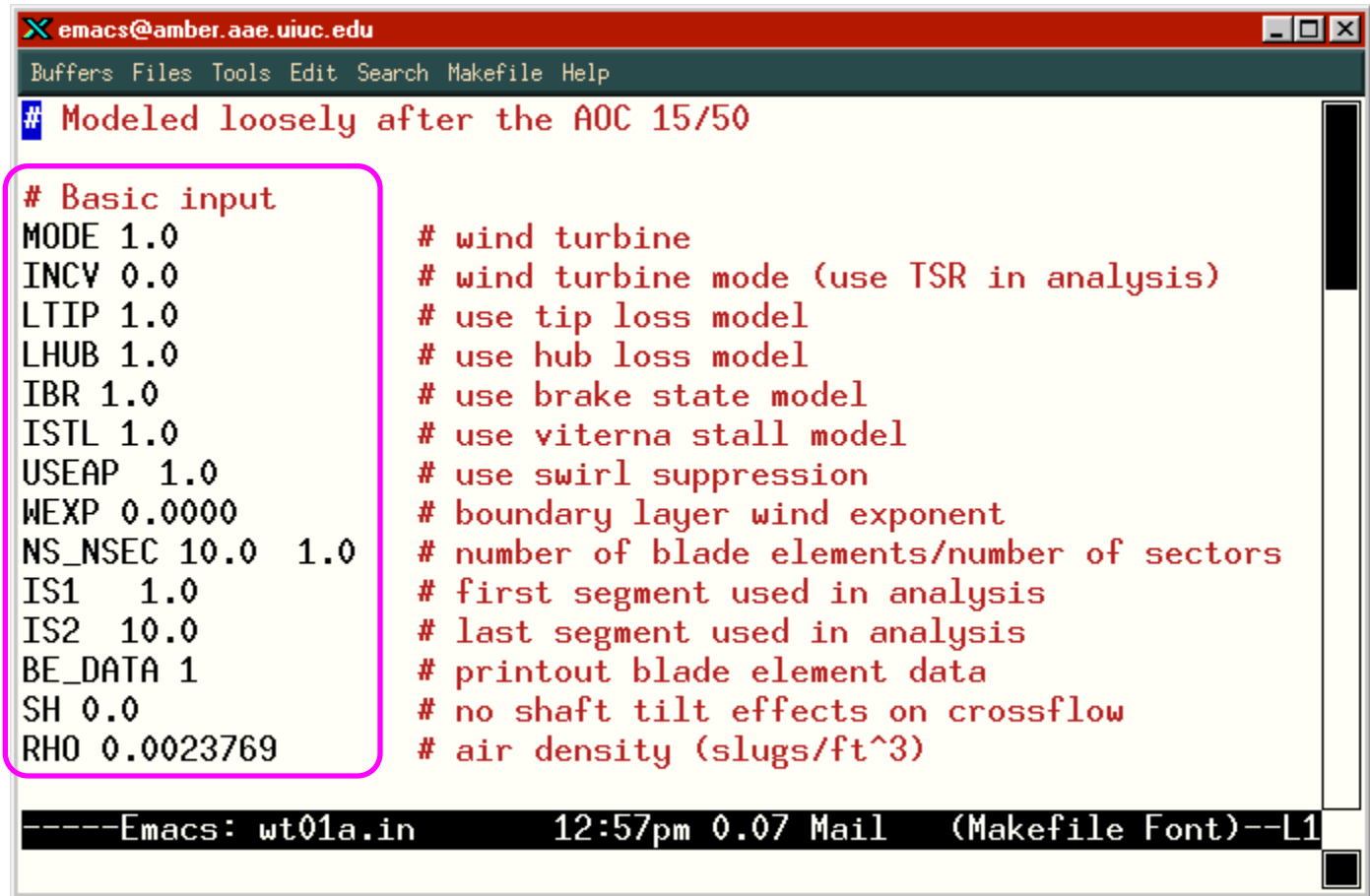
- Generates ascii text files at runtime



Input File Structure

- Basic Input Lines - A Walk through the File wt01a.in

*All data
similar
to PROP*



```
emacs@amber.aae.uiuc.edu
Buffers Files Tools Edit Search Makefile Help

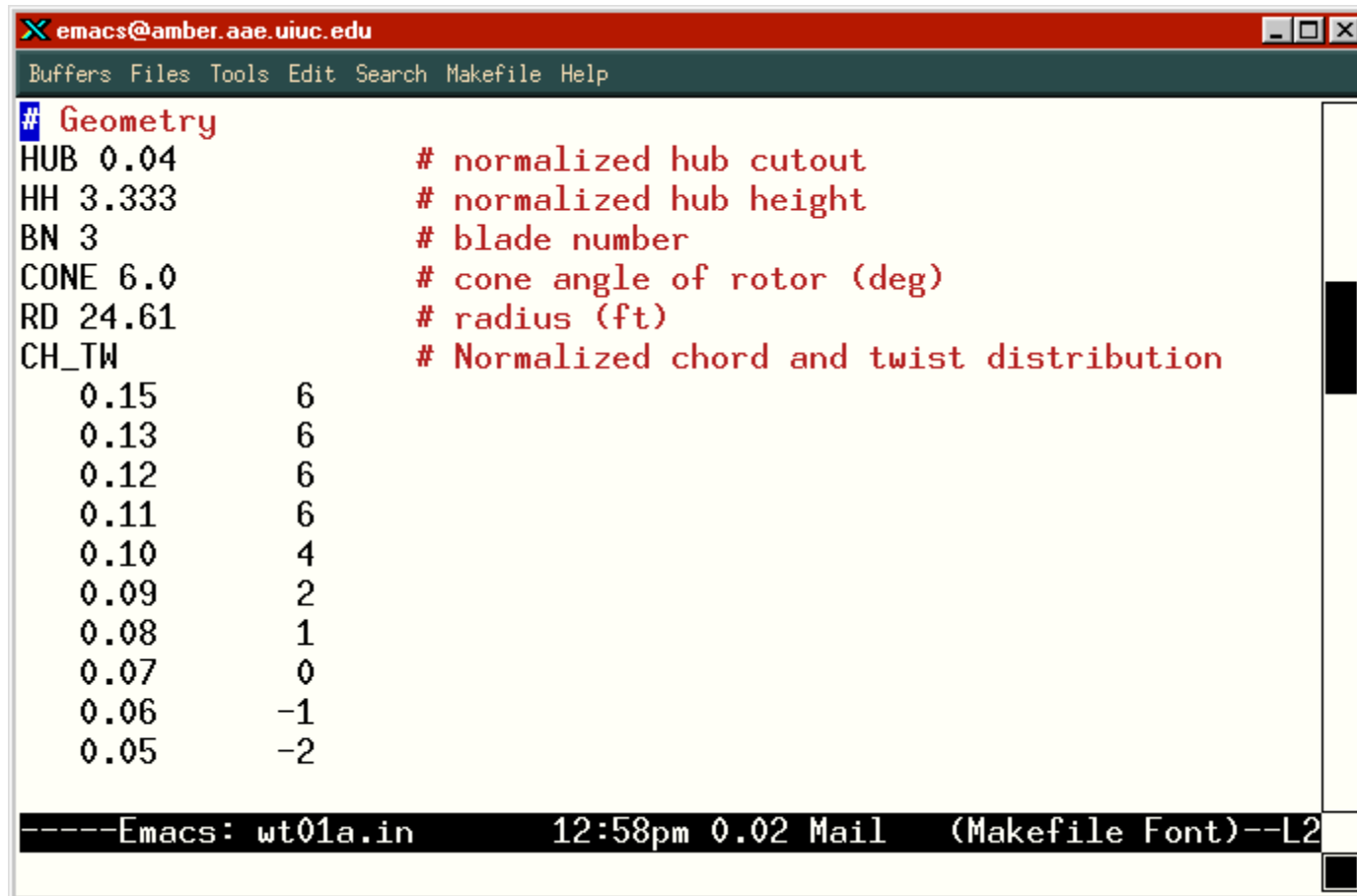
# Modeled loosely after the AOC 15/50

# Basic input
MODE 1.0          # wind turbine
INCV 0.0          # wind turbine mode (use TSR in analysis)
LTIP 1.0          # use tip loss model
LHUB 1.0          # use hub loss model
IBR 1.0           # use brake state model
ISTL 1.0          # use viterna stall model
USEAP 1.0         # use swirl suppression
WEXP 0.0000       # boundary layer wind exponent
NS_NSEC 10.0 1.0  # number of blade elements/number of sectors
IS1 1.0           # first segment used in analysis
IS2 10.0          # last segment used in analysis
BE_DATA 1         # printout blade element data
SH 0.0            # no shaft tilt effects on crossflow
RHO 0.0023769     # air density (slugs/ft^3)

-----Emacs: wt01a.in 12:57pm 0.07 Mail (Makefile Font)--L1
```



- Geometry Lines



The screenshot shows an Emacs window titled 'emacs@amber.aae.uiuc.edu'. The menu bar includes 'Buffers', 'Files', 'Tools', 'Edit', 'Search', 'Makefile', and 'Help'. The main text area contains the following content:

```
# Geometry
HUB 0.04          # normalized hub cutout
HH 3.333          # normalized hub height
BN 3              # blade number
CONE 6.0          # cone angle of rotor (deg)
RD 24.61          # radius (ft)
CH_TW            # Normalized chord and twist distribution
  0.15           6
  0.13           6
  0.12           6
  0.11           6
  0.10           4
  0.09           2
  0.08           1
  0.07           0
  0.06          -1
  0.05          -2
```

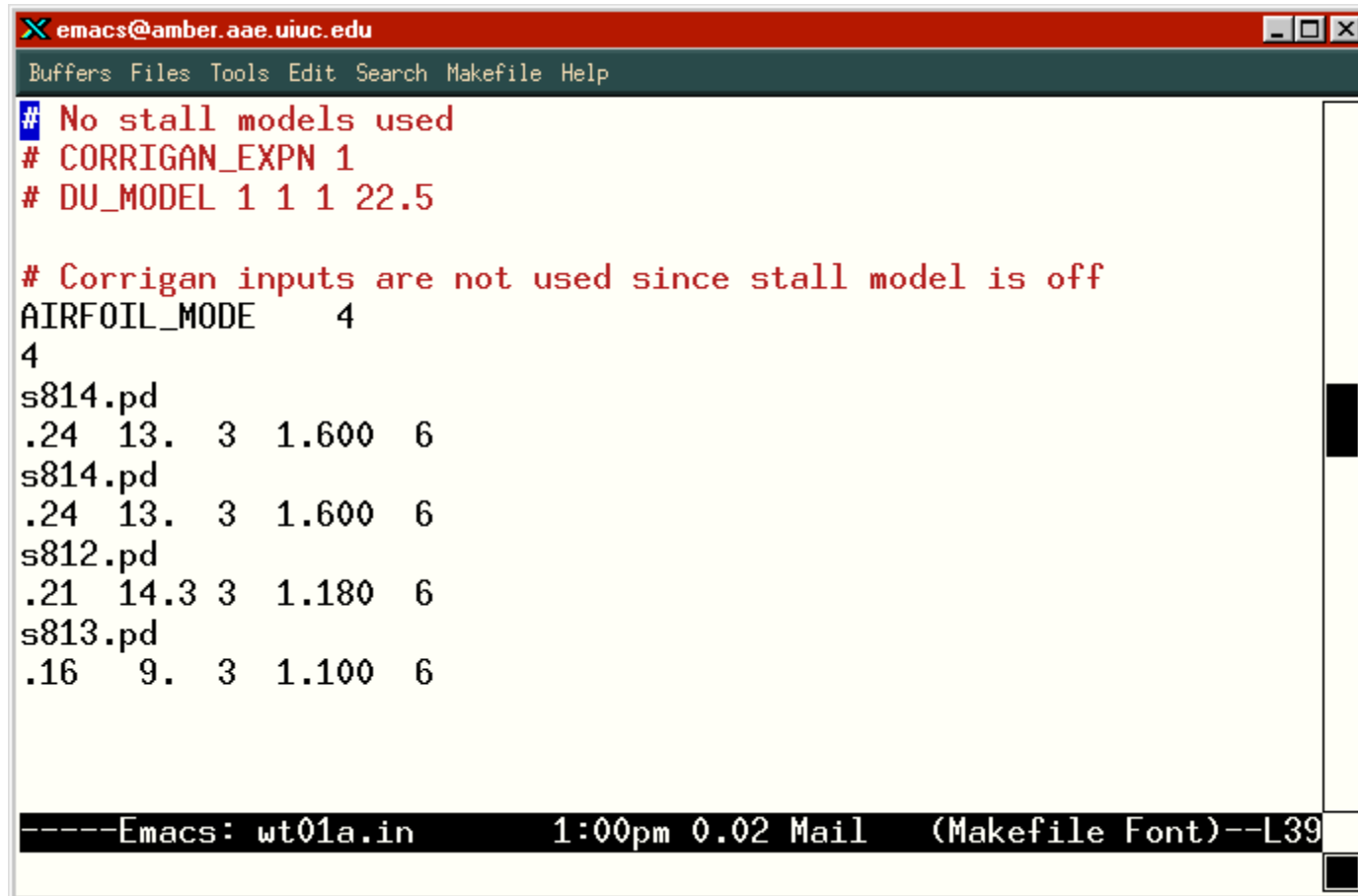
The status bar at the bottom displays: '----Emacs: wt01a.in 12:58pm 0.02 Mail (Makefile Font)--L2'.



- Airfoil Data Input - The process
 - Airfoil files are input
 - => AIRFOIL_MODE line
 - Then they are assigned locations along the blade to make up the airfoil family
 - => AIRFOIL_FAMILY line
 - More than one airfoil family can be specified
 - => Additional AIRFOIL_FAMILY lines are allowed
 - Then specify which family to use
 - => USE_AIRFOIL_FAMILY line



- Stall Models and Airfoil Data File Lines



The screenshot shows an Emacs window titled 'emacs@amber.aae.uiuc.edu'. The menu bar includes 'Buffers', 'Files', 'Tools', 'Edit', 'Search', 'Makefile', and 'Help'. The main text area contains the following lines of code:

```
# No stall models used
# CORRIGAN_EXPN 1
# DU_MODEL 1 1 1 22.5

# Corrigan inputs are not used since stall model is off
AIRFOIL_MODE    4
4
s814.pd
.24 13.  3  1.600  6
s814.pd
.24 13.  3  1.600  6
s812.pd
.21 14.3 3  1.180  6
s813.pd
.16  9.  3  1.100  6
```

The status bar at the bottom displays: '-----Emacs: wt01a.in 1:00pm 0.02 Mail (Makefile Font)--L39'.



- Details

Mode 4 (alfa-cl-cd format)

4 Files follow

Filename: #1, #2, #3, #4

Corrigan inputs (ignored)

Airfoil stall angle

Stall delay angle (increment)

t/c

```
emacs@amber.aae.uiuc.edu
Buffers Files Tools Edit Search Makefile Help
# No stall models used
# CORRIGAN_EXPN 1

# Corrigan inputs are not used since stall model is off
AIRFOIL_MODE 4
4
s814.pd .24 13. 3 1.600 6
s814.pd .24 13. 3 1.600 6
s812.pd .21 14.3 3 1.180 6
s813.pd .16 9. 3 1.100 6
```

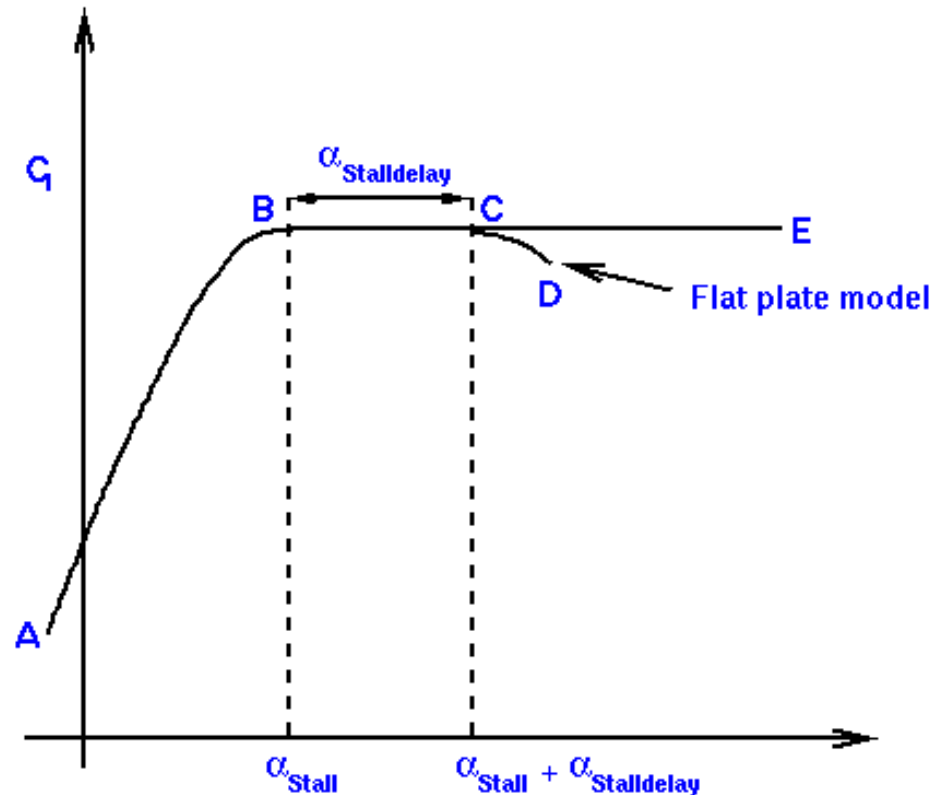
File	t/c	Stall angle (deg)	Stall delay angle (deg)	Corrigan inputs (ignored)
s814.pd	.24	13.	3	1.600 6
s814.pd	.24	13.	3	1.600 6
s812.pd	.21	14.3	3	1.180 6
s813.pd	.16	9.	3	1.100 6



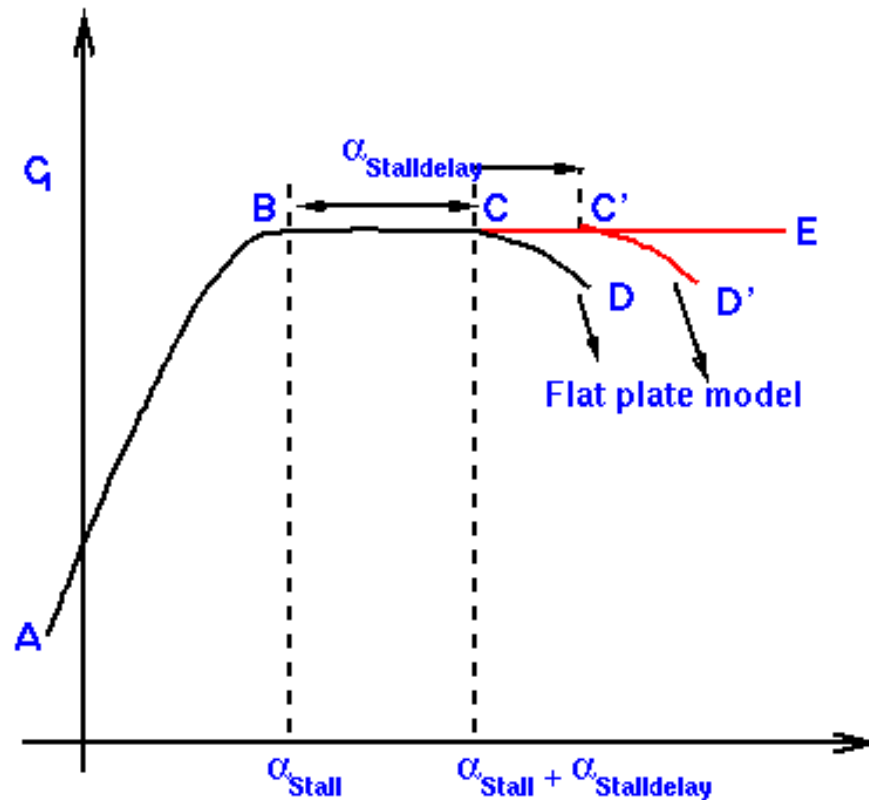


Detour: Using the Stall Angle and Stall Delay Angle

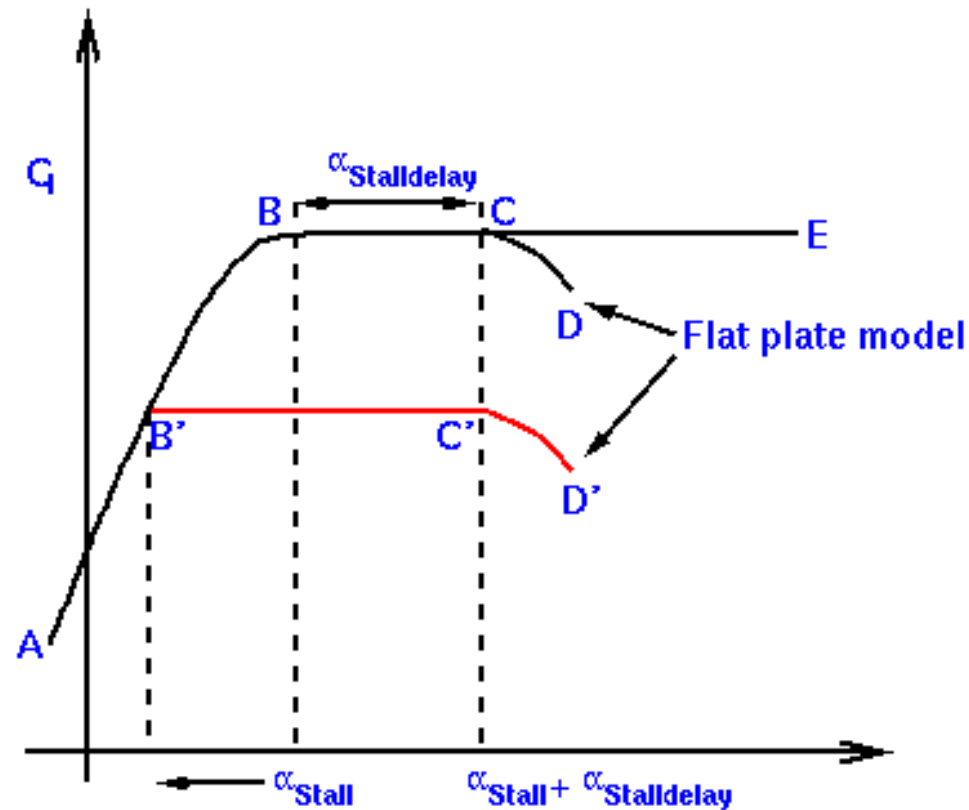
- Input data in .pd file:
A-B-C-E
- PROPID uses:
A-B-C-D
- Data past C from flat plate stall model
- Data from C-E ignored



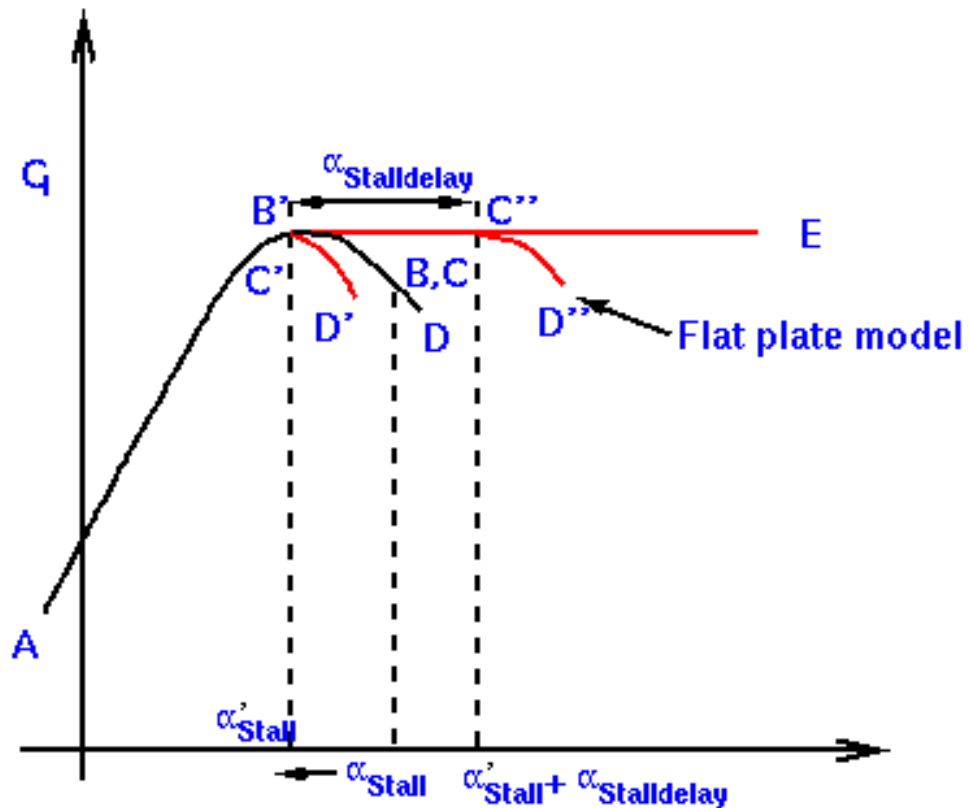
- Effect of increasing the stall delay angle $C \Rightarrow C'$ (models sensitivity to post stall effects)
- PROPID uses: A-B-C'-D'



- Effect of changing the stall angle $B \Rightarrow B'$ with a larger stall delay angle increment (models using lower lift airfoils)
- PROPID uses: $A-B'-C'-D'$



- To use only experimental data:
 - Set the stall angles to the experimental values (B)
 - Set the stall delay angle increment to zero (B = C)
- PROPID uses:
A-B'-B/C



- PROPID Run: wt02a.in
 - wt02a.in includes
 - Lines to generate airfoil data as it is being used during the prop analysis => “A” data
 - Lines to generate airfoil data for use in PROP => “B” data
 - Change the airfoil stall delay angles and use PROPIDplotter_v10.xls to show the “B” data files
 - Uncomment the CORRIGAN_EXPN line to see the effect of turning on the Corrigan model
 - As changes are made, observe the changes in annual energy production as reported by the REPORT lines at the end of the file



- Airfoil Family Lines

Airfoil locations →

.0000	1
.3000	2
.7500	3
1.0000	4

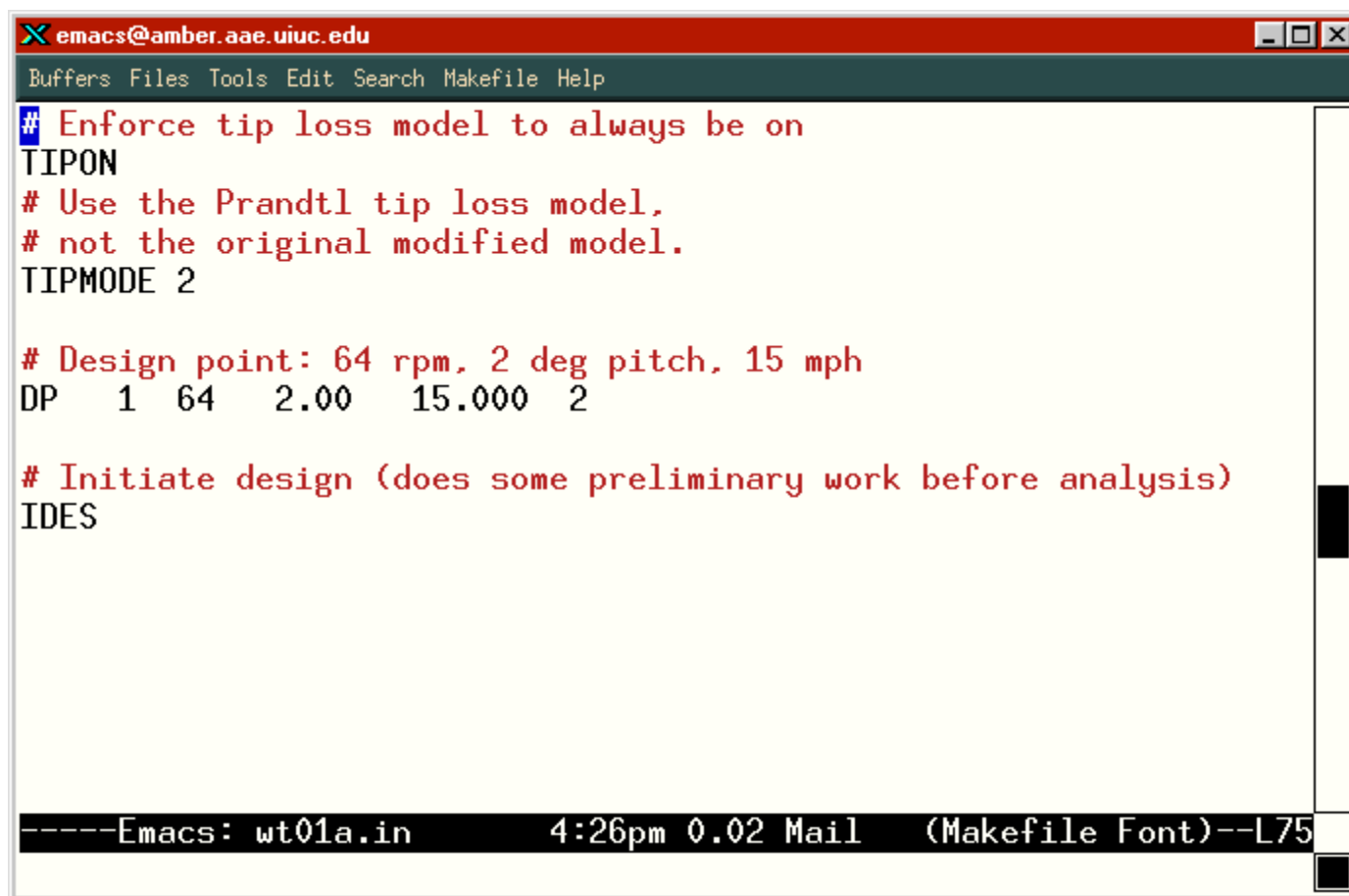
→ *Airfoil indexes*

```
emacs@amber.aae.uiuc.edu
Buffers Files Tools Edit Search Makefile Help
# airfoil family 1 with 4 airfoils
# r/R-location and airfoil index
AIRFOIL_FAMILY      4
.0000 1
.3000 2
.7500 3
1.0000 4
# use the first airfoil family (the one above)
USE_AIRFOIL_FAMILY  1

-----Emacs: wt01a.in      4:06pm 0.01 Mail  (Makefile Font)--L57
```



- Tip Loss, DP and IDES Lines



The screenshot shows an Emacs window titled 'emacs@amber.aae.uiuc.edu'. The menu bar includes 'Buffers', 'Files', 'Tools', 'Edit', 'Search', 'Makefile', and 'Help'. The main text area contains the following configuration lines:

```
# Enforce tip loss model to always be on
TIPON
# Use the Prandtl tip loss model,
# not the original modified model.
TIPMODE 2

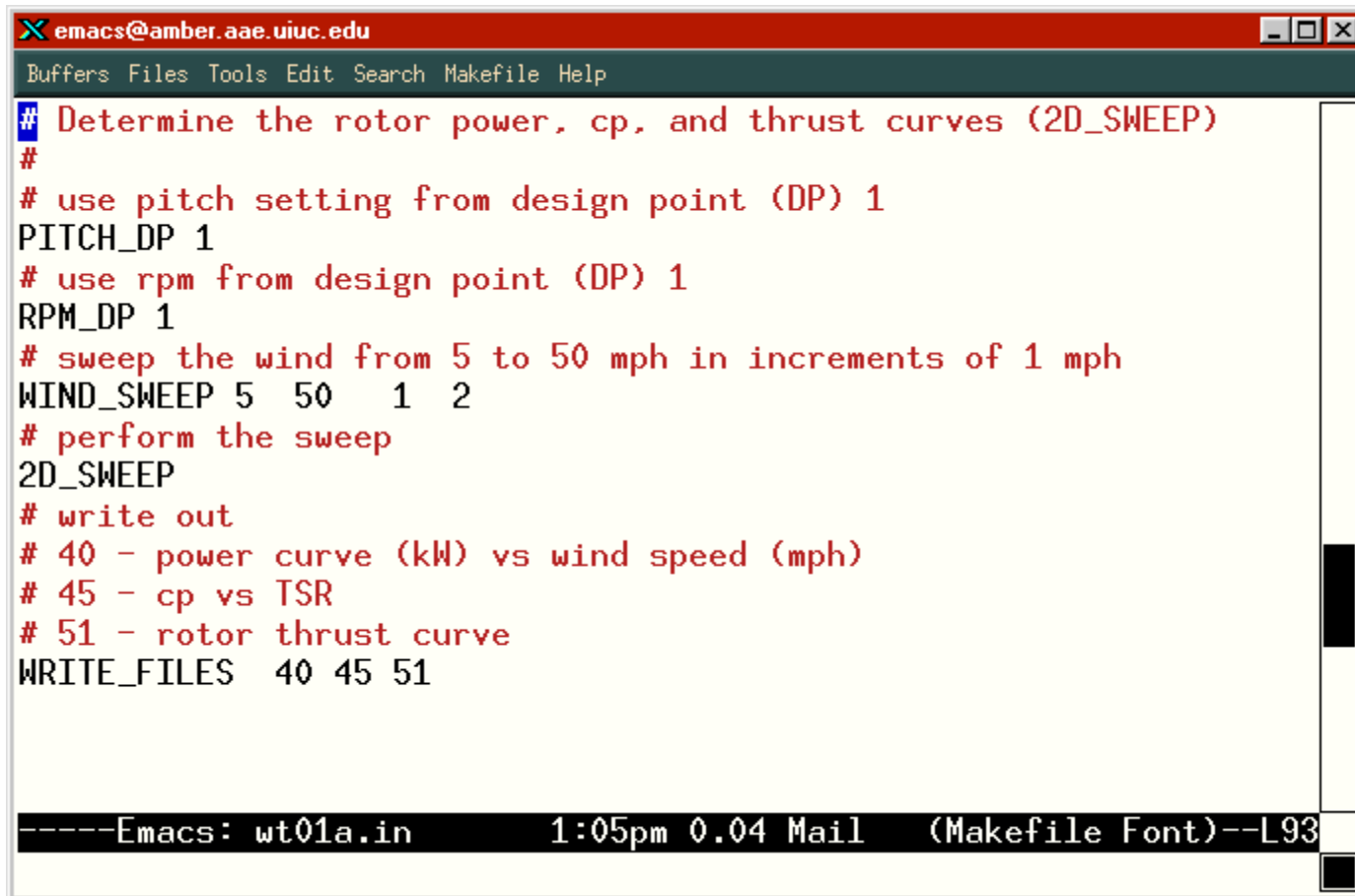
# Design point: 64 rpm, 2 deg pitch, 15 mph
DP 1 64 2.00 15.000 2

# Initiate design (does some preliminary work before analysis)
IDES
```

The status bar at the bottom displays: '----Emacs: wt01a.in 4:26pm 0.02 Mail (Makefile Font)--L75'.



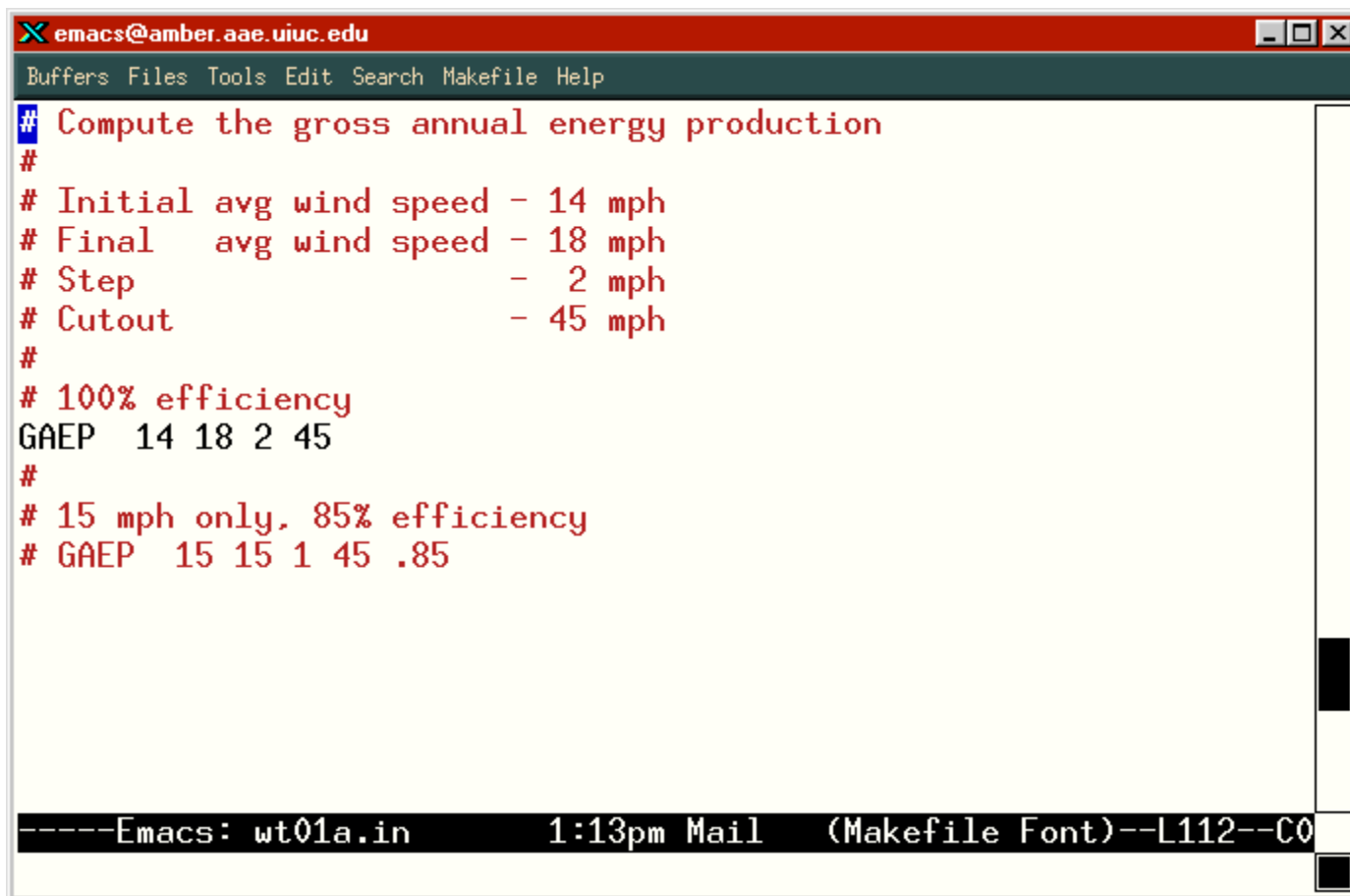
- 2D_SWEEP Lines for Power Curve



```
emacs@amber.aae.uiuc.edu
Buffers Files Tools Edit Search Makefile Help
# Determine the rotor power, cp, and thrust curves (2D_SWEEP)
#
# use pitch setting from design point (DP) 1
PITCH_DP 1
# use rpm from design point (DP) 1
RPM_DP 1
# sweep the wind from 5 to 50 mph in increments of 1 mph
WIND_SWEEP 5 50 1 2
# perform the sweep
2D_SWEEP
# write out
# 40 - power curve (kW) vs wind speed (mph)
# 45 - cp vs TSR
# 51 - rotor thrust curve
WRITE_FILES 40 45 51
-----Emacs: wt01a.in 1:05pm 0.04 Mail (Makefile Font)--L93
```



- GAEP Lines for Annual Energy Production



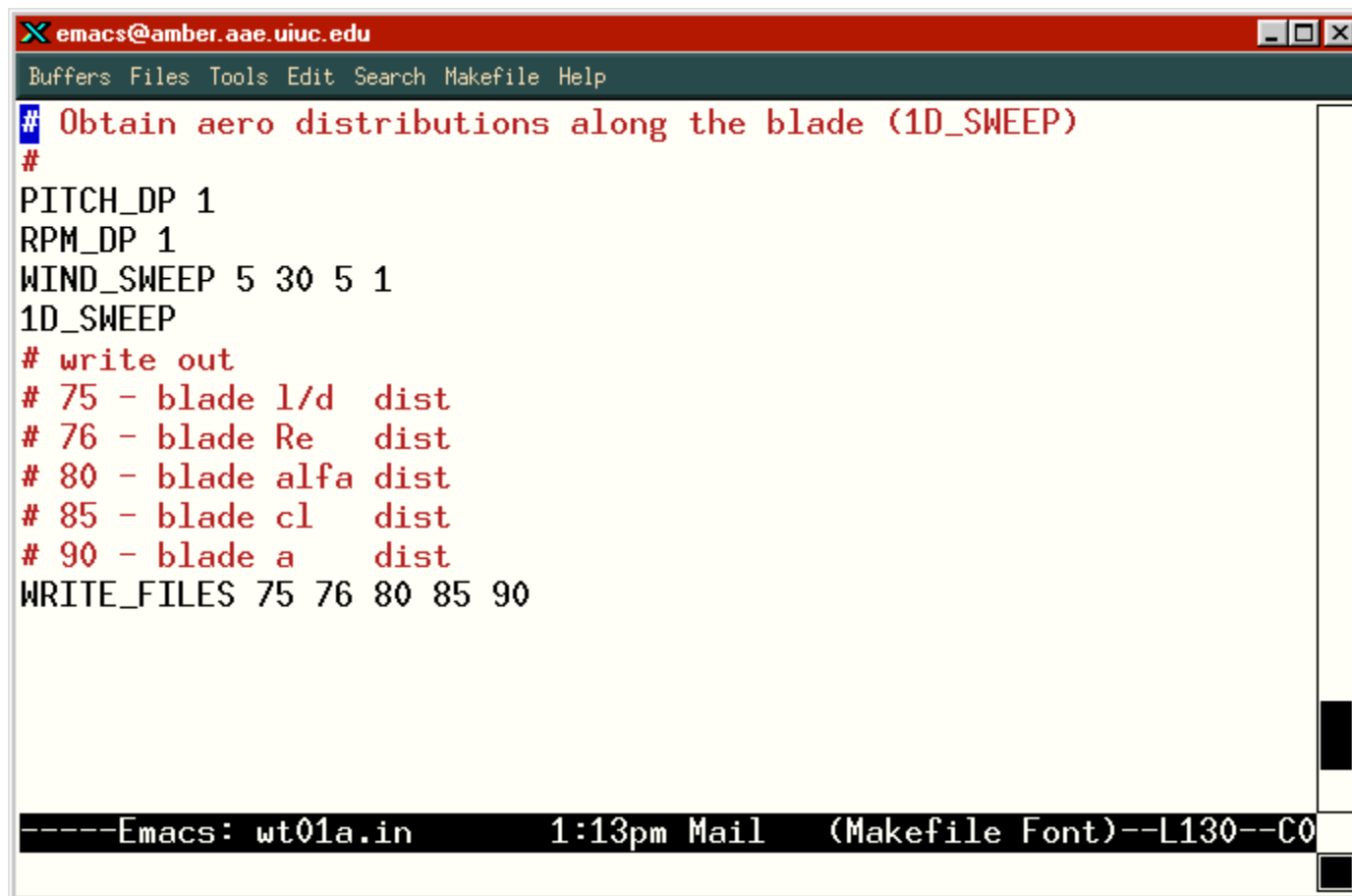
The image shows a screenshot of an Emacs text editor window. The title bar at the top reads 'emacs@amber.aae.uiuc.edu'. Below the title bar is a menu bar with the following items: 'Buffers', 'Files', 'Tools', 'Edit', 'Search', 'Makefile', and 'Help'. The main text area contains several lines of text in red font, which are comments in a configuration file. The text is as follows:

```
# Compute the gross annual energy production
#
# Initial avg wind speed - 14 mph
# Final   avg wind speed - 18 mph
# Step                - 2 mph
# Cutout              - 45 mph
#
# 100% efficiency
GAEP 14 18 2 45
#
# 15 mph only, 85% efficiency
# GAEP 15 15 1 45 .85
```

At the bottom of the window, there is a status bar with the following text: '-----Emacs: wt01a.in 1:13pm Mail (Makefile Font)--L112--C0'.



- 1D_SWEEP Lines for Blade Characteristics



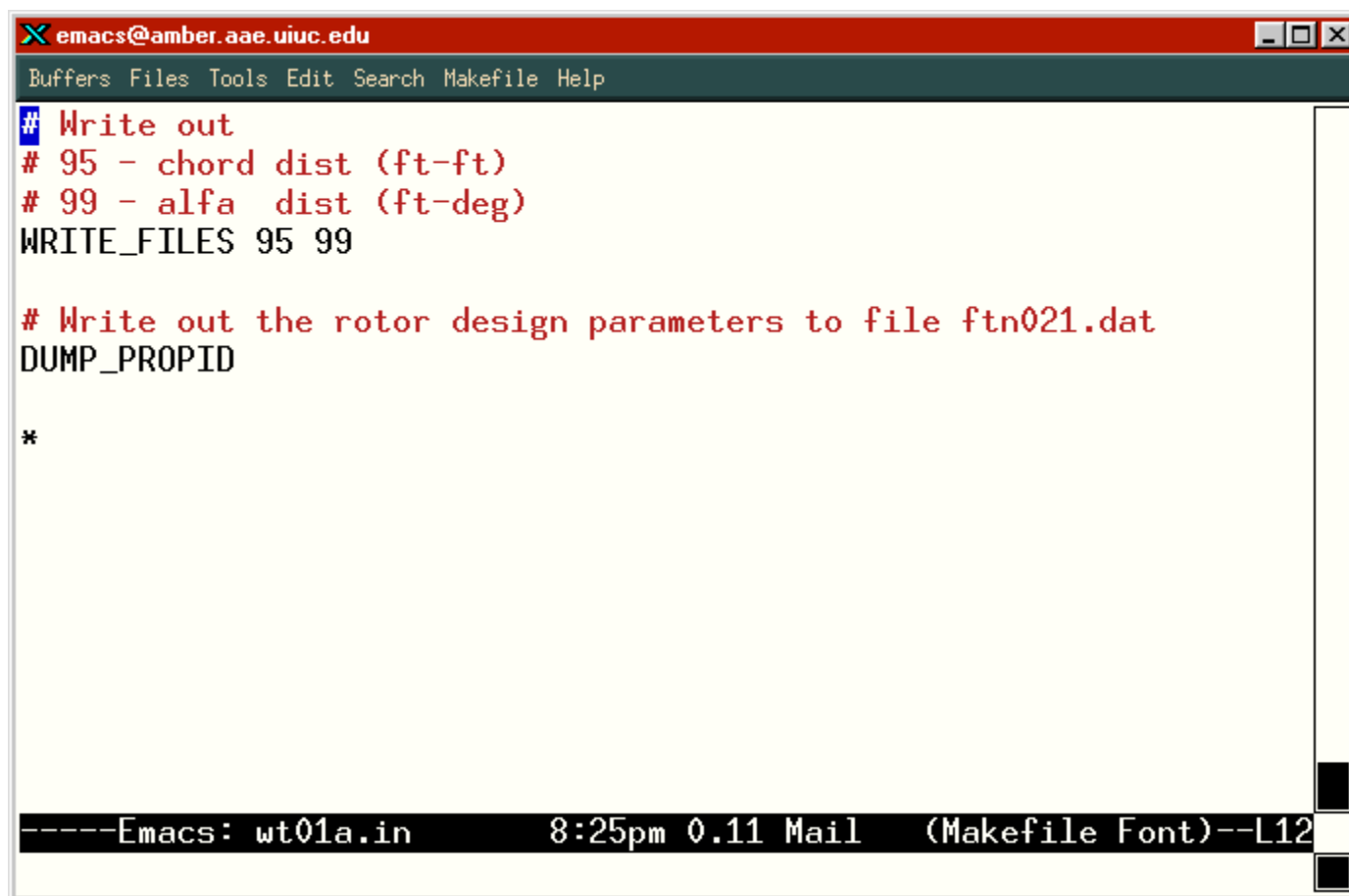
The image shows a screenshot of an Emacs window. The title bar at the top reads 'emacs@amber.aae.uiuc.edu'. Below the title bar is a menu bar with 'Buffers', 'Files', 'Tools', 'Edit', 'Search', 'Makefile', and 'Help'. The main text area contains the following text:

```
# Obtain aero distributions along the blade (1D_SWEEP)
#
PITCH_DP 1
RPM_DP 1
WIND_SWEEP 5 30 5 1
1D_SWEEP
# write out
# 75 - blade l/d dist
# 76 - blade Re dist
# 80 - blade alfa dist
# 85 - blade cl dist
# 90 - blade a dist
WRITE_FILES 75 76 80 85 90
```

At the bottom of the window, there is a status bar with the text: '-----Emacs: wt01a.in 1:13pm Mail (Makefile Font)--L130--C0'.



- Blade Geometry Files and Dump File



```
emacs@amber.aae.uiuc.edu
Buffers Files Tools Edit Search Makefile Help
# Write out
# 95 - chord dist (ft-ft)
# 99 - alfa dist (ft-deg)
WRITE_FILES 95 99

# Write out the rotor design parameters to file ftn021.dat
DUMP_PROPID

*

-----Emacs: wt01a.in      8:25pm 0.11 Mail  (Makefile Font)--L12
```



Misc. Notes

- propid-doc.txt syntax - line continuation '-'

*All on
one line
in the
input file*

```
emacs@amber.aae.uiuc.edu
Buffers Files Tools Edit Search Makefile Help
line> AIRFOIL_MODE 4 # airfoil data is in order of alfa, cl, cd
<IAF>
<AFFILE(1)>
<AFTHK(1)> <AFSTALL(1)> <STDELAY(1)> I -
<CLMAXN(1)> <ALINSERT(1)> I <DUSTART<1>> <DUEND<1>>
...
<AFFILE(JAF)>
<AFTHK(JAF)> <AFSTALL(JAF)> <STDELAY(JAF)> I -
<CLMAXN(JAF)> <ALINSERT(JAF)> I <DUSTART<JAF>> <DUEND<JAF>>
...
<AFFILE(IAF)>
<AFTHK(IAF)> <AFSTALL(IAF)> <STDELAY(IAF)> I -
<CLMAXN(IAF)> <ALINSERT(IAF)> I <DUSTART<IAF>> <DUEND<IAF>>

# AFFILE(.) - airfoil file name pd.*
# AFTHK(.) - airfoil thickness
# AFSTALL(.) - airfoil stall angle of attack
# STDELAY(.) - stall delay of the airfoil (i.e., where you want the
-----Emacs: propid-doc.txt 1:20pm 0.05 Mail (Makefile Font)--L194-
Wrote /home/m-selig/propid5080/doc/propid-doc.txt
```



- Input lines with optional data / propid-doc.txt syntax

'|' indicates optional data

```

emacs@amber.aae.uiuc.edu
Buffers Files Tools Edit Search Makefile Help
>>line> FIXPD          # w/ no arguments this also turns off fixpd, toggles
>>line> FIXPD | <FIXPD> | <ITEST> # fixed rated (maximum) power for varia
                                # machines. Note that when using this o
                                # Cp and other quantities are not corre
                                # fixed power (done in svanl2.f).
                                # If itest = 1, then determine the powe
                                # in the corner of the power curve,
                                # otherwise use 0 which is the default.
                                # itest=1 is recommended.
                                # Line only works with one tsr, pitch,
                                # Thus, you cannot do a TSR_SWEEP line.
                                # If no arguments are given, the previo
                                # is turned off...then you can use a TS

>>line> GAEP | <GVMIN> <GVMAX> <GVINC> <GVCUT> | <GENEFF>
    # If the optional GVMIN, etc are not used, then gaep.f will try to read
    # fort.44 (runfile.seacc) --- the original seacc input file.
    # GVMIN is min average wind speed in mph
    # GVMAX is max average wind speed in mph
-----Emacs: propid-doc.txt  1:07pm Mail  (Makefile Font)--L614--C0--32%
  
```

- For example: 'FIXPD 700'
- No inline comments: 'FIXPD 700 # will crash code'



- PROPID Run: wt03a.in
 - Analysis lines removed
 - Includes only geometry and airfoil data
 - Generates airfoil data at blade segments for use on other codes, e.g. PROP
- More cases are provided in the runs folder along with the short description of each case.
See the file “00-wt-series.txt” for more details.
- See Part 2-3 to continue.

