Input File for Actuator Disk in NSU3D

Actuator Disk

The actuator disk model is a low-fidelity method for analyzing the performance of a propeller or rotor. The propeller or rotor is represented by a disk (without thickness) or a cylinder (with thickness), which is subject to the influence of the blades but allows the flow to pass through the propeller or rotor. Because no physical blade geometry is simulated, the influence of the rotor is enforced by the aerodynamic loading model in the actuator disk method. Therefore, the aerodynamic loading model plays a critical role in the actuator disk method.

Three types of load models are possible:

- Assumed distribution: For a given thrust coefficient C_T and power coefficient C_Q, the loading can be obtained by assuming a prescribed disk load distribution, such as a linear distribution in the radial direction.
- Prescribed loading: The loading is given by other methods or by test data.
- Blade-element theory loading: If the blade geometry is known, the blade-element method can be applied to compute the loading for the actuator disk. The flow velocities combined with the blade geometry and rotational speed can be used to obtain the effective local angle of attack. With the local Mach number and the effective angle of attack, the lift/drag coefficients can be obtained from sectional airfoil CL/CD-AoA-Ma tables or charts and used to prescribe the appropriate momentum source terms.

Input File for Actuator Disk

Listing shows an example input file for the actuator disk with the user input loading. The input file includes four blocks:

- **actdisk_info**: the line No.5 to No.11 in the Listing 1. The general information is defined in this block.
  - nsystem : the number of systems
  - nrotor : the number of rotors
  - nblade : the number of blades
  - nairfoil : the number of airfoils
  - ref_length : the ratio of the physical length and the grid length
  - ref_length_unit : the unit of the physical length
- **actdisk_system**: the line No. 14 to No. 18 in the Listing 1. The system information is defined here:
  - system_name : the name of the system
  - gravity_center : the gravity center coordinates of the system
  - gravity_center_unit : the unit of the gravity center
  - loadtype : loading type: 1, uniform; 2, linear; 3, blade element; 4, user input
- **actdisk_rotor**: the line No. 23 to No. 37 in the Listing 1. The rotor information is defined here:
  - rotation_rate : the rotation speed of the rotor
  - rotation_unit : the unit of the rotation speed
  - hub_coord : the coordinates of the rotor hub
  - hub_unit : the unit of the coordinates
  - shaft_axis : the vector direction of rotor shaft
  - zero_azimuth_axis : the vector direction of the zero azimuth direction
  - blade_count : the number of blades
  - station_unit : the unit of the user input stations(required if loadtype=4)
  - loading_unit : the unit of the user input loading(required if loadtype=4)
  - loading_sta : the user input stations(required if loadtype=4)
  - loading : the user input loading(required if loadtype=4)
- **actdisk_blade**: the line No. 40 to No. 47 in the Listing 1. The blade information is defined here:
  - station_unit : the unit of the stations
  - chord_sta : the radial stations of the chord table
  - chord_unit : the unit of the blade chord
  - chord : the blade chord table
  - twist_sta : the radial stations of the twist angle table
  - twist_unit : the unit of the twist angle table
  - twist : the twist angle table

Listing 1: example of user input loading file: *input.actdisk*

```
! DHC propeller, actuator disk, user input loading
! 05/2021

! Initialization namelist for sea level standard atmosphere
&actdisk_info
  nsystem            = 1,
  nrotor             = 1,
  nblade             = 1,
  nairfoil           = 0,
  ref_length         = 1.0,  ! L_physical / L_grid
  ref_length_unit    = "in"
/

&actdisk_system
  system_name            = "System",
  gravity_center(1:3)    = 263.92656, 166.94613, 173.2,
  gravity_center_unit    = "in",
  loadtype               = 4                    ! user input loading type
/

! The DHC propeller is a six-blade rotor with 2 degree forward tilt.

&actdisk_rotor
  rotation_rate          = -875.0,              !
  rotation_unit          = "rpm",
  hub_coord(1:3)         = 263.92656, 166.94613, 173.2,
  hub_unit               = "in",
  shaft_axis(1:3)        =-0.99939,    -0.03490,     0.0, !
  zero_azimuth_axis(1:3) =-0.03490,     0.99939,     0.0, !
  blade_count(1)         = 6,                   ! Six blade rotor
!
! use input loading
!
  station_unit           = "in"
  loading_sta            = 16.2, 20.25, 24.3, 36.45, 48.6, 56.7, 64.8, 72.9, 76.95, 78.975,
  loading_unit           = "psf"
  loading                =  6.9, 12.6,  18.4, 35.3,  49.6, 56.5, 58.0, 50.1, 38.2,  27.6,
/

&actdisk_blade
  station_unit      = "in",
  chord_sta(1:2)    = 16.2,  81.0,
  chord_unit        = "in",
  chord(1:7)        = 13.,   13.,
  twist_sta(1:10)   = 16.2, 20.25, 24.3, 36.45, 48.6, 56.7, 64.8, 72.9, 76.95, 78.975,
  twist_unit        = "deg",
  twist(1:10)       = 53.6699, 48.8389, 44.9440, 35.8130, 29.6512, 26.7167, 24.1371, 21.8975, 20.7773, 20.1965,
/
```

For other loading type, there are some different inputs. Listing 2 shows the input file for the actuator disk with the blade element loading. Please be noted that difference:

- **actdisk_info**: the line No.9 in the Listing 2. nairfoil is eight instead of zero.
- **actdisk_system**: the new line No. 18 in the Listing 2. Also loadtype is 3, which means the blade element loading.
  - init_collective : the initail collective angle
- **actdisk_rotor**: there is no definition for the user input loading here.
- **actdisk_blade**: two new lines No. 42 and 43 in the Listing 2 define the airfoils
  - airfoil_sta : the radial stations of the airfoils
  - airfoil : the airfoils table
- **actdisk_airfoil**: the line No.46 to No. 54 in the Listing 2 define the different airfoil files in c81 format:
  - airfoil_file : the airfoil file name

Listing 2: example of blade element loading input file: *input.actdisk.blade*

```
1  ! input file for DHC propeller with blade element loading
2  ! 05/2021
3
4  ! Initialization namelist for sea level standard atmosphere
```

```
&actdisk_info
  nsystem            = 1,
  nrotor             = 1,
  nblade             = 1,
  nairfoil           = 8,
  ref_length         = 1.0,  ! L_physical / L_grid
  ref_length_unit    = "in"
/

&actdisk_system
  system_name            = "System",
  gravity_center(1:3)    = 263.92656, 166.94613, 173.2,
  gravity_center_unit    = "in",
  init_collective        = 30.4,
  loadtype               = 3                   ! blade element loading type
/

! The DHC propeller is a six-blade rotor with 2 degree forward tilt.

&actdisk_rotor
  rotation_rate          = -875.0,
  rotation_unit          = "rpm",
  hub_coord(1:3)         = 263.92656, 166.94613, 173.2,
  hub_unit               = "in",
  shaft_axis(1:3)        =-0.99939,    -0.03490,     0.0,
  zero_azimuth_axis(1:3) =-0.03490,     0.99939,     0.0,
  blade_count(1)         = 6,                  ! Six blade rotor
/

&actdisk_blade
  station_unit      = "in",
  chord_sta(1:8)    = 18.032,  23.032,  33.032,  43.032,  53.032,  63.032,  73.032,  80.032,
  chord_unit        = "in",
  chord(1:8)        = 13.338,  13.533,  13.680,  13.760,  13.689,  12.970,   9.950,   4.316,
  twist_sta(1:8)    = 18.032,  23.032,  33.032,  43.032,  53.032,  63.032,  73.032,  80.032,
  twist_unit        = "deg",
  twist(1:8)        = 22.030,  19.202,  13.851,   8.180,   2.343,  -3.334,  -7.965, -10.709,
  airfoil_sta(1:8)  = 18.032,  23.032,  33.032,  43.032,  53.032,  63.032,  73.032,  80.032,
  airfoil(1:8)      = 1, 2, 3, 4, 5, 6, 7, 8,
/

&actdisk_airfoil
  airfoil_file(1)  = "../af/s1.c81"
  airfoil_file(2)  = "../af/s2.c81"
  airfoil_file(3)  = "../af/s3.c81"
  airfoil_file(4)  = "../af/s4.c81"
  airfoil_file(5)  = "../af/s5.c81"
  airfoil_file(6)  = "../af/s6.c81"
  airfoil_file(7)  = "../af/s7.c81"
  airfoil_file(8)  = "../af/s8.c81"
/
```

Listing 3 shows the input file for the actuator disk with the prescribed linear distribution loading. Please be noted that difference:

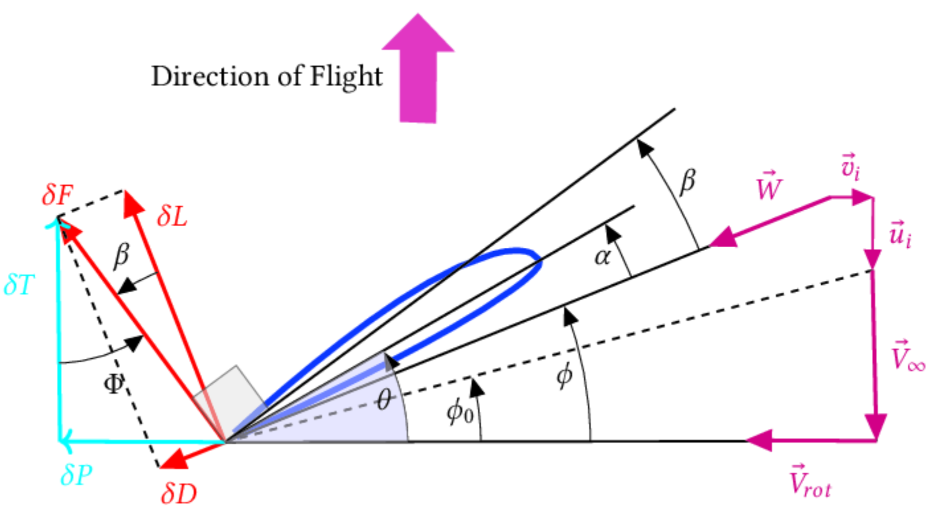
- **actdisk_system**: the new line No. 18 to No. 20 in the Listing 3. Also loadtype is 2, which means the prescribed loading with linear distribution.
  - target_id : loading ID: "FX", "FY" or "FZ"
  - target_value : prescribed loading value
  - target_unit : unit of the loading
- **actdisk_rotor**: there is no definition for the user input loading here.

Listing3: example of linear prescribed loading input file: *input.actdisk.linear*

```
1  ! DHC propeller, actuator disk, user input loading
2  ! 05/2021
3
4  ! Initialization namelist for sea level standard atmosphere
5  &actdisk_info
6    nsystem            = 1,
7    nrotor             = 1,
8    nblade             = 1,
```

```
  nairfoil            = 0,
  ref_length          = 1.0,  ! L_physical / L_grid
  ref_length_unit     = "in"
/

&actdisk_system
  system_name               = "System",
  gravity_center(1:3)       = 263.92656, 166.94613, 173.2,
  gravity_center_unit       = "in",
  target_id(1)              = "FX",
  target_value(1)           = 5400,
  target_unit(1)            = "lb"
  loadtype                  = 2                   ! prescribed loading type, linear distribution
/

! The DHC propeller is a six-blade rotor with 2 degree forward tilt.

&actdisk_rotor
  rotation_rate             = -875.0,             !
  rotation_unit             = "rpm",
  hub_coord(1:3)            = 263.92656, 166.94613, 173.2,
  hub_unit                  = "in",
  shaft_axis(1:3)           =-0.99939,    -0.03490,     0.0, !
  zero_azimuth_axis(1:3)    =-0.03490,     0.99939,     0.0, !
  blade_count(1)            = 6,                  ! Six blade rotor
/

&actdisk_blade
  station_unit        = "in",
  chord_sta(1:2)      = 16.2,  81.0,
  chord_unit          = "in",
  chord(1:7)          = 13.,   13.,
  twist_sta(1:10)     = 16.2, 20.25, 24.3, 36.45, 48.6, 56.7, 64.8, 72.9, 76.95, 78.975,
  twist_unit          = "deg",
  twist(1:10)         = 53.6699, 48.8389, 44.9440, 35.8130, 29.6512, 26.7167, 24.1371, 21.8975, 20.7773, 20.1965,
/
```

Figure: Illustration of the blade element



The definition of the twist angle in the block **actdisk_blade** is different in the blade element loading(loadtype=3) from other loading type. In the loadtype=3, the twist angle is the blade install angle, shown as theta - theta_0 in the figure above, where theta_0 is the initial collective angle(line No. 18 in Listing 2). For other loading types, the twist angle is the total force angle, shown as phi+beta in the figure above.