heliPypter Documentation

Release 0.0.7

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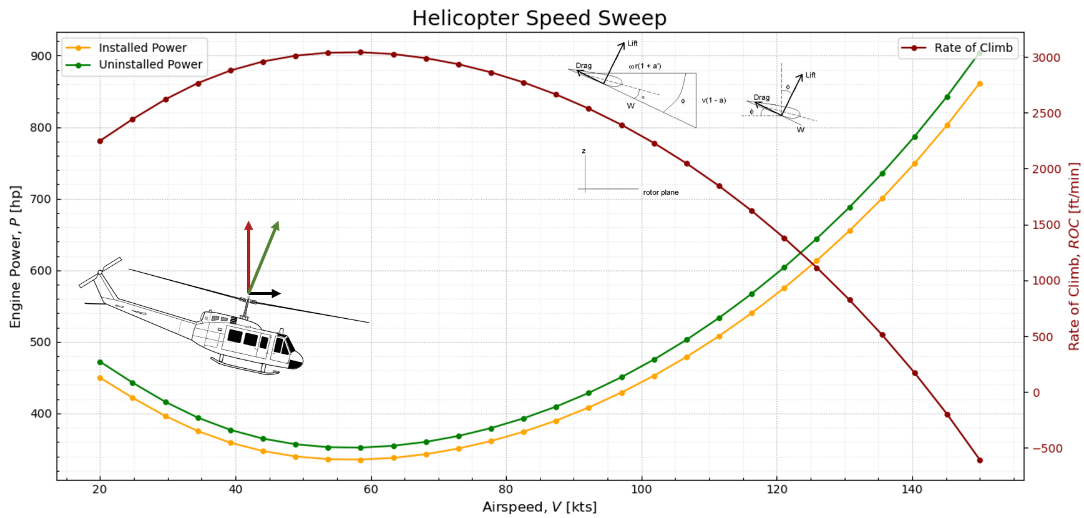
Contents:



heliPypter is a package for rotorcraft performance evaluation. Rotorcraft attributes are provided as input, and performance characteristics such as Engine Horsepower, Specific Range, and Fuel consumption are evaluated.

heliPypter has an object oriented philosophy, so different rotorcraft configurations can be built, modified, and evaluated quickly, with the same methods. The classes have methods for Hover in and out of Ground Effect (HOGE and HIGE), as well as forward flight.

Under the hood, briefly speaking, the code applies Momentum Theory assuming constant chord ideal twist. Correction factors can be supplied to align results with tapered, linearly twisted blades. For forward flight, Glauert's Model is used.

CHAPTER 1

Installation

For most sytems, the easiest way to install this package is through the Python Package Index:

` $ pip install helipypter `

heliPypter requires pandas and scikit-aero, which should be automatically installed by pip, if you need them.

The project homepage is *here <https://github.com/Czarified/helipypter>*.

CHAPTER 2

Analysis With heliPypter

2.1 Basic Flight Performance

Using heliPypter, performance for a traditional helicopter with single main and tail rotors can be evaluated. The first step is defining all the inputs (there are many). The details of all inputs are fully documented on the API page.

Warning: Units are important, so make sure they are all Imperial! Metric and automated units with Pint may be supported in a future release. If you want it, post on the issues page.

The Helicopter class takes numeric weight values for fuel, and a single lumped value for all other masses. It then adds the remaining fuel weight and empty mass whenver you call the heli.GW property. Let's use an empty weight fraction to generate this helicopter.

```
import helipypter.vehicles as vh

# Empty weight fraction
EW_frac = 0.528
# Total Gross Weight
GW_total = 5000
# Crew Weight
w_crew = 200
# Trapped Fluids
w_fluids = 13

w_empty = EW_frac*GW_total + w_crew + w_fluids
# Our payload is 6 people @ 213 lbs each
w_payload = 6*213
w_fuel = GW_total - w_empty - w_payload

doc_chopper = vh.Helicopter(name='Documentation Helicopter Spec',
                            MR_dia = 35,
                              MR_b = 4,
```

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```
                            MR_ce = 10.4,
                         MR_Omega = 43.2,
                           MR_cd0 = 0.0080,
                           TR_dia = 5.42,
                             TR_b = 4,
                            TR_ce = 7,
                         TR_Omega = 239.85,
                           TR_cd0 = 0.015,
                         GW_empty = w_empty,
                          GW_fuel = w_fuel,
                       GW_payload = w_payload,
                         download = 0.03,
                               fe = 12.9,
                           l_tail = 21.21,
                             S_vt = 20.92,
                            cl_vt = 0.22,
                            AR_vt = 3
                                 )
```

Note: The Main Rotor Blade incompressible minimum drag, *MR_cd0*, is a vehicle characteristic. If we could clean up this blade drag term, it would logically affect all flight performance, so it's included here in the base definition of the vehicle.

The same goes for the airframe equivalent flat-plate drag, *fe*. If we were to perform an airframe drag cleanup design cycle on our vehicle, we can reduce this term here, or scale it however you want.

The Helicopter class has many default values. Some aren't shown here, so it's always good idea to check the vehicle definition using a simple print function.

```
print(doc_chopper)

-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
       Documentation Helicopter Spec
Rotors: ('MR', 'TR')
-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
Main Rotor Inputs:
           MR_dia:  35.000 [ft]
             MR_b:   4.000 []
            MR_ce:  10.400 [in]
         MR_Omega:  43.200 [rad/s]
           MR_cd0:   0.008 []
             MR_R:  17.500 []
             MR_A: 962.113 []
          MR_vtip: 756.000 []
           MR_sol:   0.063 []
-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
Tail Rotor Inputs:
           TR_dia:   5.420 [ft]
             TR_b:   4.000 []
            TR_ce:   7.000 [in]
         TR_Omega: 239.850 [rad/s]
           TR_cd0:   0.015 []
             TR_R:   2.710 []
             TR_A:  23.072 []
          TR_vtip: 649.993 []
```

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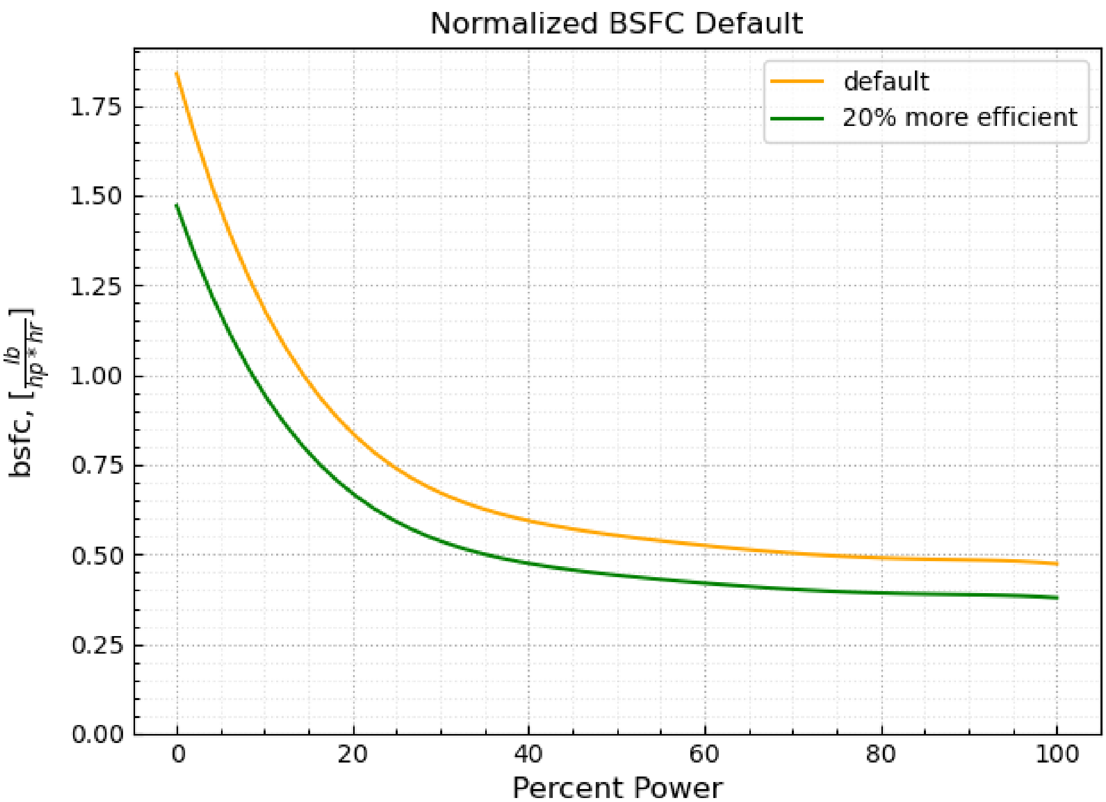
```
          TR_sol:   0.274 []
-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
Airframe Data:
        GW_empty: 2853.000 [lbs]
         GW_fuel: 869.000 [lbs]
      GW_payload: 1278.000 [lbs]
        download:   0.030 [.%]
     HIGE_factor:   1.200 []
              fe:  12.900 [ft2]
          l_tail:  21.210 [ft]
            S_vt:  20.920 [ft2]
           cl_vt:   0.220 []
           AR_vt:   3.000 []
-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
Engine Data:
      eta_MRxsmn:   0.985 [.%]
      eta_TRxsmn:   0.971 [.%]
     eta_xsmn_co:   0.986 [.%]
        eta_inst:   0.950 [.%]
       xsmn_lim: 674.000 [hp]
        pwr_lim: 813.000 [hp]
-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
```

Note: Not shown here are the engine Brake-Specific Fuel Consumption factors. Four factors can be provided, defining a polynomial function to return the bsfc, in *[lbs/(hp*hr)]*. See `helipypter.vehicles.Helicopter` method *Helicopter.bsfc*.



The heli object can now be called to hover, burn fuel, idle, lookup engine power, or fly. However, before we can perform any flight maneuvers, atmospheric properties must be supplied. Here, we create an Environment class. For example, to create a Sea-level standard atmosphere and hover at it:

```
atm = vh.Environment(alt=0)

output = heli.HOGE(atm)
print('-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-')
print('{:^45}'.format('Results - HOGE'))
print('-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-')
for k,v in doc_chopper.HOGE(atm).items():
    print('{:>17}:   {:>7.4}'.format(k, v))
```

Hover Out of Ground Effect (HOGE) returns dictionary of the flight point predictions. Sometimes, dictionary output isn't the easiest to read, even though it's easy to lookup. So we created a simple loop to print the data.

```
-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
            Results - HOGE
-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
                a:     5.717
          delta_0:   0.009518
               Ct:   0.003937
        TR_thrust:     291.1
             Cq_i:   0.0001787
             Cq_v:       0.0
             Cq_0:   7.502e-05
             Cq_1:  -1.037e-05
```

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```
          Cq_2:   1.317e-05
            Cq:   0.0002565
             Q:   6.174e+03
          P_MR:   2.425e+05
         HP_MR:     485.0
         HP_TR:      45.3
       SHP_ins:     566.0
     SHP_unins:     595.8
           sfc:    0.4982
```

Note: One of the optional inputs to the HOGE method is *k_i*. This number is the correction factor for non-uniform inflow, linear twist, and taper. It's defaulted to 1.1, and will typically be between 1 and 1.15.

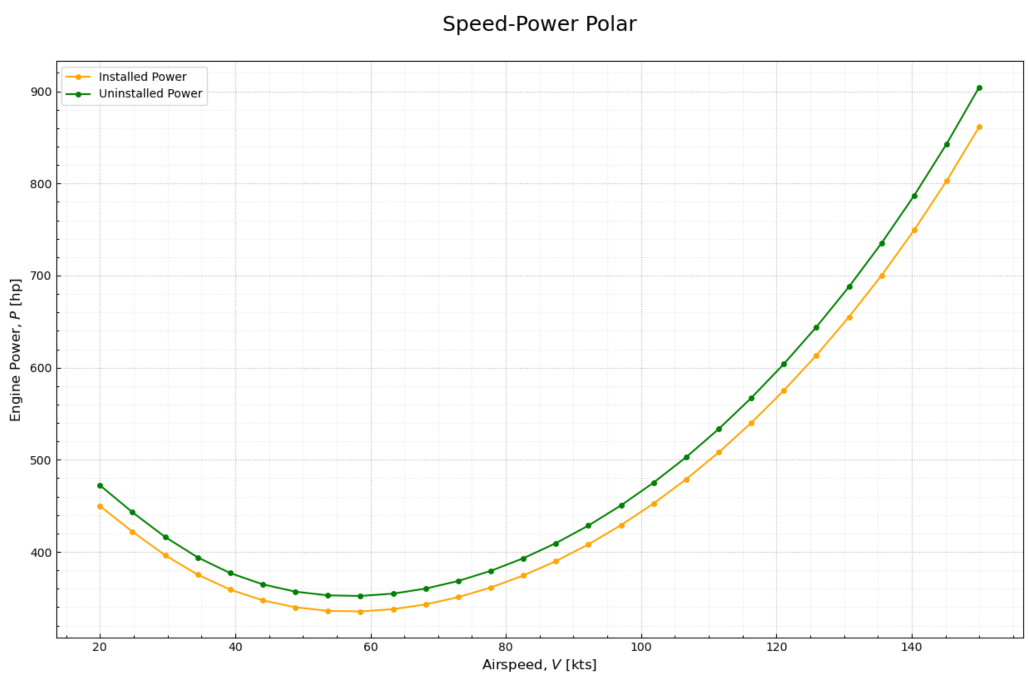
Forward flight performance can be evaluated just as easily. Let's perform a speed sweep from 20 knots to 150 knots. The forward_flight method just takes an Environment for atmospheric properties, and either a single or list of airspeeds. This method returns a pandas dataframe that has several columns. It's sometimes hard to view this data, so heliPypter has convenient plotting functions.

```
import numpy as np
import helipypter.funcs as func

# Create an array of 14 equally spaced airspeed values
# This is just a little shorthand and not necessary.
speeds = np.linspace(20, 150, num=14)

data = doc_chopper.forward_flight(atm, speeds)

fig, ax = func.speed_power_polar(data)
```



There's lots of other data in this dataframe, and built-in functions exist to plot range and rate-of-climb. For now we'll stop here and move on to mission analysis.

2.2 Mission Analysis

The first step here is obviously to create a mission. Currently, there's no built-in classes representing a mission, because the contents of a mission are a simple collection of *mission points*, where each point has maneuver inputs. This data structure is very easily represented as a *namedtuple*. You can decide how you want to approach the specifics of mission analysis, this just one example. All helipypter classes should be flexible enough to fit your needs.

Note: In the future, this may change with some built-in missions, or a slightly different structure to make aircraft sizing straight-forward. At the time of creation, this was enough for me and I didn't need to bother with the overhead of a custom class.

```
from collections import namedtuple

Point = namedtuple('MissionPoint', ['maneuver', 'altitude', 'duration', 'speed'])
startup = Point(maneuver='idle', altitude=0, duration=1, speed=0)
takeoff = Point(maneuver='IRP', altitude=0, duration=1, speed=0)
climb_0 = Point('MCP', 0, 5, 1000)
cruise_0 = Point('flight', 5000, 160, 110)
hover_1 = Point('hover', 0, 1, 0)
loiter = Point('loiter', 5000, 10, 60)
unload = Point('unload', 0, 5, 1278)
ground = Point('idle', 0, 1, 0)

mission = (startup, takeoff,
       climb_0, cruise_0, loiter,
       hover_1, unload, hover_1,
       climb_0, cruise_0,
       hover_1, ground
      )
```

We've got a mission now, let's create a function to run the helicopter through the mission, burning fuel and changing weight as we go. We'll just use logging to print everything out to the console. If you have multiple missions and vehicles and you want to compare performance across them, you'll probably want to write all this data to anoter dataframe or dictionary.

This is a lot of clunky code. I'm sure it can be written to be more pythonic. Most of it is just our logging statements, though. Essentially, we step through the mission and evaluate each point, determining the fuel required, removing that fuel weight from the total fuel weight, and logging the results.

```
import logging

def mission_loop(heli, mission):
'''This temp function performs all the logic to simulate the fuel burn of a mission.''
↪'
    # Mission Loop
    logging.info('')
    logging.info('')
    logging.info('-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-')
    logging.info('{:^45}'.format('Project Spec Mission'))
    logging.info('-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-')
```

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```
    # Initialize the range tracker
    mission_range = 0
    for point in mission:
        if point.maneuver == 'idle':
            fuel = heli.idle()/60 * point.duration
            heli.burn(fuel)
            logging.info(f'Idled for {point.duration}[mins].')
            logging.info(f'   Burned {fuel:.2f}[lbs] of fuel.')
            logging.info(f'   New GW = {heli.GW:.2f}[lbs], fuel: {heli.GW_fuel:.2f}')
            logging.info('')

        elif point.maneuver == 'hover':
            # Actually calculate the fuel cost for
            # hovering at an exact weight and altitude
            data = heli.HOGE(vh.Environment(point.altitude))
            fuel = data['sfc']*data['SHP_unins']*point.duration/60
            heli.burn(fuel)
            logging.info(f'Hovered for {point.duration}[mins], burning {fuel:.2f}
↪[lbs] of fuel.')
            logging.info(f'   New GW = {heli.GW:.2f}[lbs], fuel: {heli.GW_fuel:.2f}')
            logging.info('')

        elif point.maneuver == 'loiter':
            data = heli.forward_flight(vh.Environment(point.altitude), point.speed)
            fuel = data.SHP_uninst[0]*data.bsfc[0]/60 * point.duration
            heli.burn(fuel)
            logging.info(f'Loitered at {point.speed}[kts] for {point.duration}[mins].
↪')
            logging.info(f'   Burned {fuel:.2f}[lbs] of fuel.')
            logging.info(f'   New GW {heli.GW:.2f}[lbs], fuel: {heli.GW_fuel:.2f}')
            logging.info('')

        elif point.maneuver == 'IRP':
            # IRP is the engine rated limit
            sfc = heli.bsfc(100)
            fuel = sfc*1*heli.pwr_lim/60 * point.duration
            heli.burn(fuel)
            logging.info(f'Ran at IRP for {point.duration}[mins].')
            logging.info(f'   Burned {fuel:.2f}[lbs] of fuel.')
            logging.info(f'   New GW = {heli.GW:.2f}[lbs], fuel: {heli.GW_fuel:.2f}')
            logging.info('')

        elif point.maneuver == 'MCP':
            # MCP is defined as 95% of IRP
            sfc = heli.bsfc(95)
            fuel = sfc*0.95*heli.pwr_lim/60 * point.duration
            heli.burn(fuel)
            logging.info(f'MCP Climb for {point.duration}[mins] @ {point.speed}[ft/
↪min].')
            logging.info(f'   Burned {fuel:.2f}[lbs] of fuel.')
            logging.info(f'   New GW = {heli.GW:.2f}[lbs], fuel: {heli.GW_fuel:.2f}')
            logging.info('')
            mission_range += 120*point.duration/60   # 120 kts has more ROC than 1000␣
↪TODO: Calculate this.

        elif point.maneuver == 'flight':
            data = heli.forward_flight(vh.Environment(point.altitude), point.speed)
```

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```
            fuel = point.duration/data.SR[0]
            heli.burn(fuel)
            logging.info(f'Forward flight for {point.duration}[nm] @ {point.speed}
↪[kts].')
            logging.info(f'    Burned {fuel:.2f}[lbs] of fuel.')
            logging.info(f'    New GW = {heli.GW:.2f}[lbs], fuel: {heli.GW_fuel:.2f}')
            logging.info('')
            mission_range += point.duration

        elif point.maneuver == 'climb':
            # Represents a hover climb/descent NOT @ MCP
            # There's no range credit for a "climb" maneuver instead of an "MCP"␣
↪maneuver.
            data = heli.HOGE(vh.Environment(point.altitude), Vroc=point.speed)
            fuel = data['sfc']*data['SHP_unins']*point.duration/60
            heli.burn(fuel)
            logging.info(f'Climb for {point.duration}[min] @ {point.speed}[ft/min]')
            logging.info(f'    Burned {fuel:.2f}[lbs] of fuel.')
            logging.info(f'    New GW = {heli.GW:.2f}[lbs], fuel: {heli.GW_fuel:.2f}')
            logging.info('')

        elif point.maneuver == 'unload':
            logging.info(f'Landed! Unloading {point.speed}[lbs] of cargo.')
            heli.unload(point.speed)
            fuel = heli.idle()/60 * point.duration
            heli.burn(fuel)
            logging.info(f'Idled for {point.duration}[mins], burning {fuel:.2f}[lbs]␣
↪of fuel.')
            logging.info(f'    New GW = {heli.GW:.2f}[lbs], fuel: {heli.GW_fuel:.2f}')
            logging.info('')

    logging.info('')
    logging.info(f'Mission Complete! {heli.GW_fuel:.2f} [lbs] of fuel remaining.')
    logging.info(f'Total Range = {mission_range:.2f}[nm]')
    logging.info('-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-')

mission_loop(doc_chopper, mission)
```

Results:

```
2020-05-02 21:16:07,914 -  INFO -  -.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
2020-05-02 21:16:07,914 -  INFO -              Project Spec Mission
2020-05-02 21:16:07,914 -  INFO -  -.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
2020-05-02 21:16:07,914 -  INFO -  Idled for 1[mins].
2020-05-02 21:16:07,914 -  INFO -     Burned 2.27[lbs] of fuel.
2020-05-02 21:16:07,914 -  INFO -     New GW = 4997.73[lbs], fuel: 866.73
2020-05-02 21:16:07,914 -  INFO -
2020-05-02 21:16:07,914 -  INFO -  Ran at IRP for 1[mins].
2020-05-02 21:16:07,914 -  INFO -     Burned 6.42[lbs] of fuel.
2020-05-02 21:16:07,914 -  INFO -     New GW = 4991.31[lbs], fuel: 860.31
2020-05-02 21:16:07,914 -  INFO -
2020-05-02 21:16:07,914 -  INFO -  MCP Climb for 5[mins] @ 1000[ft/min].
2020-05-02 21:16:07,914 -  INFO -     Burned 31.00[lbs] of fuel.
2020-05-02 21:16:07,914 -  INFO -     New GW = 4960.31[lbs], fuel: 829.31
2020-05-02 21:16:07,914 -  INFO -
2020-05-02 21:16:07,944 -  INFO -  Forward flight for 160[nm] @ 110[kts].
2020-05-02 21:16:07,944 -  INFO -     Burned 374.09[lbs] of fuel.
```

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```
2020-05-02 21:16:07,944 -  INFO -    New GW = 4586.22[lbs], fuel: 455.22
2020-05-02 21:16:07,945 -  INFO -
2020-05-02 21:16:07,974 -  INFO -  Loitered at 60[kts] for 10[mins].
2020-05-02 21:16:07,974 -  INFO -    Burned 32.14[lbs] of fuel.
2020-05-02 21:16:07,974 -  INFO -    New GW 4554.09[lbs], fuel: 423.09
2020-05-02 21:16:07,974 -  INFO -
2020-05-02 21:16:07,975 -  INFO -  Hovered for 1[mins], burning 4.60[lbs] of fuel.
2020-05-02 21:16:07,975 -  INFO -    New GW = 4549.49[lbs], fuel: 418.49
2020-05-02 21:16:07,975 -  INFO -
2020-05-02 21:16:07,975 -  INFO -  Landed! Unloading 1278[lbs] of cargo.
2020-05-02 21:16:07,975 -  INFO -  Idled for 5[mins], burning 11.34[lbs] of fuel.
2020-05-02 21:16:07,975 -  INFO -    New GW = 3260.14[lbs], fuel: 407.14
2020-05-02 21:16:07,975 -  INFO -
2020-05-02 21:16:07,975 -  INFO -  Hovered for 1[mins], burning 3.71[lbs] of fuel.
2020-05-02 21:16:07,975 -  INFO -    New GW = 3256.44[lbs], fuel: 403.44
2020-05-02 21:16:07,975 -  INFO -
2020-05-02 21:16:07,975 -  INFO -  MCP Climb for 5[mins] @ 1000[ft/min].
2020-05-02 21:16:07,975 -  INFO -    Burned 31.00[lbs] of fuel.
2020-05-02 21:16:07,975 -  INFO -    New GW = 3225.44[lbs], fuel: 372.44
2020-05-02 21:16:07,975 -  INFO -
2020-05-02 21:16:08,005 -  INFO -  Forward flight for 160[nm] @ 110[kts].
2020-05-02 21:16:08,005 -  INFO -    Burned 333.85[lbs] of fuel.
2020-05-02 21:16:08,005 -  INFO -    New GW = 2891.59[lbs], fuel: 38.59
2020-05-02 21:16:08,005 -  INFO -
2020-05-02 21:16:08,006 -  INFO -  Hovered for 1[mins], burning 3.48[lbs] of fuel.
2020-05-02 21:16:08,006 -  INFO -    New GW = 2888.11[lbs], fuel: 35.11
2020-05-02 21:16:08,006 -  INFO -
2020-05-02 21:16:08,006 -  INFO -  Idled for 1[mins].
2020-05-02 21:16:08,006 -  INFO -    Burned 2.27[lbs] of fuel.
2020-05-02 21:16:08,006 -  INFO -    New GW = 2885.84[lbs], fuel: 32.84
2020-05-02 21:16:08,006 -  INFO -
2020-05-02 21:16:08,006 -  INFO -
2020-05-02 21:16:08,006 -  INFO -  Mission Complete! 32.84 [lbs] of fuel remaining.
2020-05-02 21:16:08,006 -  INFO -  Total Range = 340.00[nm]
2020-05-02 21:16:08,006 -  INFO -  -.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
```

2.3 Technology Factors

During design of an air vehicle it can be advantageous to explore the effects of different technology factors, represented as percent reductions, on the performance. Because of heliPypter's object-oriented approach, changing these inputs is relatively straight-forward.

Using our previously-created helicopter as a base, we can update these values one by one, or all at once, it's really up to you.

```python
import copy

## Reduce the empty weight fraction
EW_factor = 0.95

# Empty weight fraction
EW_frac = 0.528
# Total Gross Weight
GW_total = 5000
```

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```
# Crew Weight
w_crew = 200
# Trapped Fluids
w_fluids = 13

w_empty = EW_factor*EW_frac*GW_total + w_crew + w_fluids
# Our payload is still 6 people @ 213 lbs each
w_payload = 6*213
w_fuel = GW_total - w_empty - w_payload

lite_args = copy.copy(args)
lite_args[11] = w_empty
lite_args[12] = w_fuel
lite_args[13] = w_payload

# Generate the new vehicle, with all other characteristics the same
lightweight = chopper_gen(lite_args)
out = pd.DataFrame(data=func.missionSim(lightweight, mission), columns=['dist', 'fuel_
↪rem', 'fuel_used'])
print(f'Lite chopper range: {out.dist.sum()}')
print(f'Lite chopper remaining fuel: {out.fuel_rem.iat[-1]:.2f}')


## Reduce the MR_cd0
## Reduce the fe
cd0_factor = 0.95
fe_factor = 0.95

clean_args = copy.copy(args)
clean_args[5] = cd0_factor*clean_args[5]
clean_args[15] = fe_factor*clean_args[15]

clean_chopper = chopper_gen(clean_args)

out = pd.DataFrame(data=func.missionSim(clean_chopper, mission), columns=['dist',
↪'fuel_rem', 'fuel_used'])
print(f'Clean chopper range: {out.dist.sum()}')
print(f'Clean chopper remaining fuel: {out.fuel_rem.iat[-1]:.2f}')



## Reduce the Induced Power Factor
## Increase the fuel efficiency of the engine
eng_fac = 0.97

# Use this k_i when calling Helicopter.hover()
k_i = 1.05

efficient_chopper = copy.copy(doc_chopper)
efficient_chopper.bsfc_0 = eng_fac*efficient_chopper.bsfc_0
efficient_chopper.bsfc_1 = eng_fac*efficient_chopper.bsfc_1
efficient_chopper.bsfc_2 = eng_fac*efficient_chopper.bsfc_2
efficient_chopper.bsfc_3 = eng_fac*efficient_chopper.bsfc_3
efficient_chopper.bsfc_4 = eng_fac*efficient_chopper.bsfc_4
efficient_chopper.bsfc_5 = eng_fac*efficient_chopper.bsfc_5

# Since this one is a copy of the old one
```

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```
# We've already burned all the fuel and unloaded
# it, so we need to reset the weight values.
efficient_chopper.refuel()
efficient_chopper.reload()

out = pd.DataFrame(data=func.missionSim(efficient_chopper, mission), columns=['dist',
↪'fuel_rem', 'fuel_used'])
print(f'Efficient chopper range: {out.dist.sum()}')
print(f'Efficient chopper remaining fuel: {out.fuel_rem.iat[-1]:.2f}')
```

From here, we can evaluate each verion on the same set of missions, and observe the change in fuel consumption. Changes to the base class aren't limited to the above. A formulaic optimization procedure could be performed on any number of variables for design optimization. Programming this operation is beyond the scope of this analysis, however, and may be included at a later date.

Let's just look at the code output. The mission range was constant (although you could change it, but I would argue the the mission should design the vehicle and not vice versa), but the remaining fuel changes with each iteration.

```
Default chopper range: 340.0
Default chopper remaining fuel: 32.84
Lite chopper range: 340.0
Lite chopper remaining fuel: 164.84
Clean chopper range: 340.0
Clean chopper remaining fuel: 42.34
Efficient chopper range: 340.0
Efficient chopper remaining fuel: 57.55
```

We can see from the above that our design is very sensitive to weight and fuel efficiency. Improvements in these areas would be more effective uses of future design resources than in cleaner aerodynamics.

CHAPTER 3

Theoretical Background

Coming soon! Please be patient, I'm a busy grad student with a big-boy job and can only work on this in my free time.

3.1 References

[1] A. Gessow and G. Jr. Myers, Aerodynamics of the Helicopter, 8th ed. College Park Press, 1985. [2] C. N. Keys, Rotary-Wing Aerodynamics Performance Prediction of Helicopters, vol. 2, 2 vols. Philadelphia, Pennsylvania: NASA Scientific and Technical Information Office, 1979.

CHAPTER 4

Python API Documentation

4.1 Vehicles

The main class in helipypter is the Helicopter.

class helipypter.vehicles.**Helicopter**(*name: str = 'Tim the Enchanter', rotors: tuple = ('MR', 'TR'), MR_dia: float = 10, MR_b: int = 2, MR_ce: float = 10.4, MR_Omega: float = 43.2, MR_cd0: float = 0.008, TR_dia: float = 2, TR_b: int = 2, TR_ce: float = 6, TR_Omega: float = 20, TR_cd0: float = 0.015, GW_empty: float = 1000, GW_fuel: float = 0, GW_payload: float = 0, download: float = 0.03, HIGE_factor: float = 1.2, fe: float = 5, l_tail: float = 15, S_vt: float = 15, cl_vt: float = 0.1, AR_vt: float = 3, eta_MRxsmn: float = 0.985, eta_TRxsmn: float = 0.9712, eta_xsmn_co: float = 0.986, pwr_acc: float = 10, eta_inst: float = 0.95, xsmn_lim: float = 674, pwr_lim: float = 813, bsfc_0: float = 1.839, bsfc_1: float = -0.08754, bsfc_2: float = 0.00252, bsfc_3: float = -3.77e-05, bsfc_4: float = 2.822e-07, bsfc_5: float = -8.331e-10*)

This class represents a helicopter with typical design features. These features are:

- Single Main Rotor,
- Single Tail Rotor,
- No shared lift or forward thrusters

The basic Helicopter class has attributes and properties (according to Python definitions). Defaults are set for all values, so be careful with results before checking that all your input values (and units) are correct!

This class uses a constant equivalent chord for all blades, and an efficiency factor must be used to estimate real performance based on this. No root cut-out is available.

HIGE (*atm*, *Thrust=None*, *delta_1: float = -0.0216*, *delta_2: float = 0.4*, *k_i: float = 1.1*, *Vroc: float = 0*) → list
This method calculates the Hover In Ground Effect performance.

This is simply the HOGE, but with a factored thrust.

HOGE (*atm*, *Thrust=None*, *delta_1: float = -0.0216*, *delta_2: float = 0.4*, *k_i: float = 1.1*, *Vroc: float = 0*) → list
This method calculates Hover Out of Ground Effect performance.

Variables

- **atm** (*class*) – An Environment class object, which provides altitude and temperature.
- **delta_1** (*float*) – The second term in the 3-part drag equation (default to -0.0216 based on literature)
- **delta_2** (*float*) – The third term in the 3-part drag equation (default to 0.4 based on literature)
- **k_i** (*float*) – The "efficiency factor" which includes losses for non-uniform inflow, and non-ideal twist.
- **Vroc** (*float*) – The vertical rate of climb, in ft/min.

Returns a, delta_0, Ct, Cq_i, Cq_v, Cq_0, Cq_1, Cq_2, Q, P_MR, P_TR, SHP_ins, SHP_unins

Return type list(float, float, float, float, float, float, float, float, float, float, float, float, float)

A 3D lift coefficient [cl/rad]

Delta_0 corrected, compressible drag coefficient (1st term in 3-term drag equation)

Ct coefficient of thrust

Cq_i coefficient of torque, induced velocity contribution

Cq_v coefficient of torque, vroc contribution

Cq_0 coefficient of torque, 1st term drag

Cq_1 coefficient of torque, 2nd term drag

Cq_2 coefficient of torque, 3rd term drag

Q Main Rotor Torque

P_MR Main Rotor required Power

P_TR Tail Rotor required Power

SHP_ins Total shaft horsepower of the installed engine

SHP_unins Total shaft horsepower of an uninstalled engine (spec)

bsfc (*pwr*) → float
This method uses the normalized bsfc curve (engine specific).

Variables **pwr** (*float*) – Percent power (eg 47%)

Returns Brake specific fuel consumption (lbs/(hp*hr))

Return type float

burn (*fuel*)
This method burns an amount of fuel, reducing the fuel weight by the amount burned.

forward_flight (*atm*, *Airspeed*) → dict
This function evaluates performance in forward flight. Airspeed (in kts) input can be a single value, or a list of the desired speed sweep.

Performance metrics such as drag, MR power, TR power, Engine power, fuel consumption, and range are evaluated.

TODO, currently df is returned: A dictionary is returned with keys for each characteristic and a list of outputs as values.

get_units (*attribute_name*) → str
Returns the units from the metadata definition of the attribute.

idle (*pwr: float = 20*)
This method evaluates the fuel consumption for ground idle operations. Fuel consumption is returned in units of lb/hr. (This is the default bsfc curve)

A ground idle power setting of 20% is assumed by default.

refuel ()
This method refuels to the fuel capacity. Capacity is defined upon vehicle creation.

reload ()
This method reloads the payload to capacity. Capacity is defined upon vehicle creation.

unload (*weight*)
This method, similar to burn, removes weight from the aircraft by unloading a weight of payload.

Although the “Environment” class isn’t a vehicle, it’s temporarily stored in the vehicles module.

class helipypter.vehicles.**Environment** (*alt: float = 0*)
This class contains all the atmospheric data used in performance calculations. All atmospheric properties are attributes of this class.

Depends on sk-aero.coesa module. Note that only input is the altitude, in feet. All units returned are automatically converted from metric to Imperial.

4.2 Functions

helipypter.funcs.**speed_power_polar** (*data*)
This function generates a standard speed-power polar plot. Input data must have columns following the standard naming convention of the helicopter class.

ie. A dataframe output from the Helicopter.forward_flight method can be directly supplied.

helipypter.funcs.**specific_range** (*data*)
This function generates a standard specific range plot. Input data must have columns following the standard naming convention of the helicopter class.

ie. A dataframe output from the Helicopter.forward_flight method can be directly supplied.

helipypter.funcs.**roc** (*data*)
This function generates a standard rate of climb plot. Input data must have columns following the standard naming convention of the helicopter class.

ie. A dataframe output from the Helicopter.forward_flight method can be directly supplied.

helipypter.funcs.**missionSim** (*heli*, *mission*) → dict
This function runs a helicopter through a mission. For each point, the fuel consumption is evaluated, and the flight distance is evaluated.

Parameters

- **heli** (*Helicopter*) – Helicopter to be analyzed.
- **mission** (*tuple(nametuple)*) – Mission profile to be analyzed.

Returns Mission data table

Return type dict

CHAPTER 5

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CHAPTER 6

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