Eli - TAARG

- DUCTED PROPELLER'S FUNCTION - TOTAL THRUST

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1 Algorithm

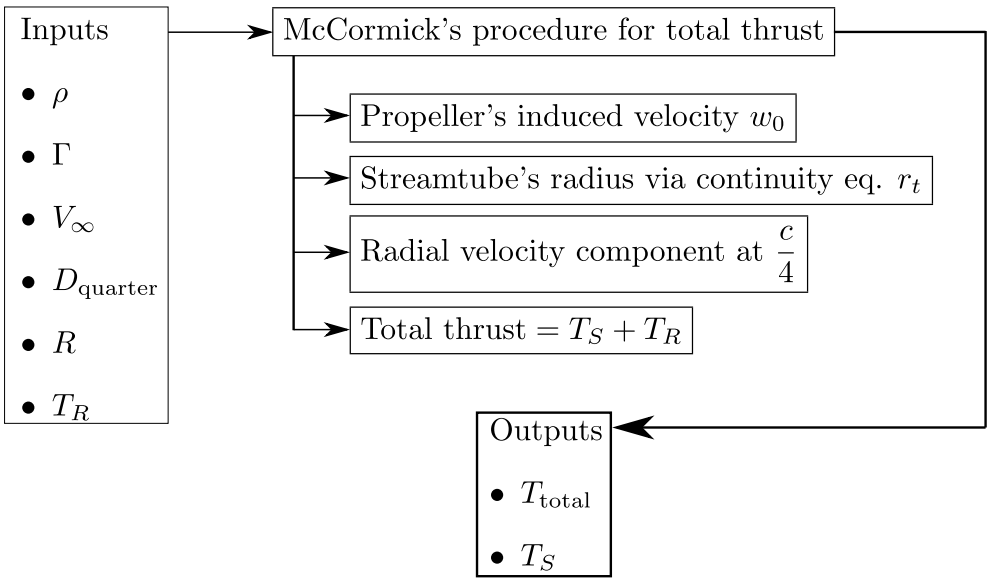

Figure 1 - 1: Flow diagram of the function `ducted_prop_thrust.m` with inputs and outputs.

In this brief document, we will describe the algorithm of the function `ducted_prop_thrust.m` based on the semi - empirical method proposed by McCormick. A simplified flow diagram for the code is shown in 1 - 1. First, the function calculates the induced velocity on the rotor's disk.

```
% ------------------------------------------------------------------------
% Propeller's induced velocity calculations
w0 = .5*(-Vinf + sqrt(Vinf^2 + 2*TR/(rho*pi*R^2)));
% ------------------------------------------------------------------------
```

Listing 1: Induced velocity function `ducted_prop_thrust.m`

Then, it's possible to calculate the upstream flow - tube's radius via the continuity equation.

```
% ------------------------------------------------------------------------
% Streamtube's radius rt calculated via the continuity
A = pi*R^2;
const = (Vinf + w0)*A;
rt = sqrt(const/(Vinf*pi));
% ------------------------------------------------------------------------
```

Listing 2: Upstream flow - tube's radius r_t function `ducted_prop_thrust.m`

Is now possible to evaluate the radial velocity component induced by the rotor at $c/4$.

```
% ------------------------------------------------------------------------
% Radial velocity component induced by the rotor at c/4
cquarter=1/4;
viRquarter = -.5*rt*w0*R^2/((R^2+cquarter^2)^1.5);
% ------------------------------------------------------------------------
```

Listing 3: v_R at $c/4$ function `ducted_prop_thrust.m`

In the last section, thrust's calculations are executed.

```
% ------------------------------------------------------------------------
% Thrust component due to the shroud
TS = -rho*viRquarter*Gamma*pi*Dquarter;
% ------------------------------------------------------------------------
% Total thrust
T = TR + TS;
% ------------------------------------------------------------------------
end
```

Listing 4: Thrust's calculations function `ducted_prop_thrust.m`

1.1 Inputs

The function accepts the following inputs:

- flow density ρ;
- ring vortex circulation Γ;
- stream velocity V_∞;
- quarter diameter D_{quarter};
- duct's radius R;
- free rotor's thrust T_R.

1.2 Outputs

The function generates the following outputs:

- total thrust T_{total};
- shroud thrust T_S.

A test case for the function `ducted_prop_thrust.m` is shown, with relative outputs.

```
% ========================================
% |Input       :                          |
% |              (rho) = 1.225 [kg/m^3]   |
% |              (Gamma) = 30 [m^2/s]     |
% |              (Vinf) = 35 [m/s]        |
% |              (Dquarter) = 2 [m]       |
% |              (R) = .9 [m]             |
% |              (TR) = 500 [N]           |
% |Output      : (T) = 729.6644 [N]       |
% |              (TS) = 229.6644 [N]      |
% |Note        :                          |
% ========================================

Dquarter = 2;
Gamma = 30;
Vinf = 35;
rho = 1.225;
R = .9;
TR = 500;

[T,TS] = ducted_prop_thrust(rho,Gamma,Vinf,Dquarter,R,TR)
```

Listing 5: Test case for the `ducted_prop_thrust.m`

1.3 Use of the function

This function must be used in conjunction with another program that provides ring vortex circulation and, thus, the isolated rotor's thrust.

2 Code listing

```
%% \ducted_prop_thrust.m
%  \brief:  A function that calculates total thrust of a ducted propeller.
%   It generates a vector with total thrust and shroud thrust as output.
%  \author: Claudio Mirabella, Christian Salzano
%  \version: 1.04
%
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%
% ================================================================================
% |Name        : ducted_prop_thrust.m                                            |
% |Author      : Claudio Mirabella, Christian Salzano                            |
% |              University of Naples Federico II.                               |
% |Version     : 1.04                                                            |
% |Date        : 25/11/2020                                                      |
% |Modified    : 11/01/2021                                                      |
% |Description : A function that calculates total thrust of a ducted propeller.  |
% |              Generates a vector with total thrust and shroud thrust as output.|
% |Reference   : Lezioni di Aerodinamica dell'Ala Rotante                        |
% |Input       :                                                                 |
% |              (rho) = Density                                                 |
% |              (Gamma) = Ring vortex circulation associated with the shroud    |
% |              (Vinf) = Stream velocity                                        |
% |              (Dquarter) = Shroud diameter at c/4                             |
% |              (R) = Shroud radius                                             |
% |              (TR) = Isolated rotor thrust                                    |
% |Output      : (T) = Total thrust generated                                    |
% |              (TS) = Thrust generated by the shroud                           |
% |Note        :                                                                 |
% ================================================================================

function [T, TS] = ducted_prop_thrust(rho, Gamma, Vinf, Dquarter, R, TR)
% ------------------------------------------------------------------
% Propeller's induced velocity calculations
w0 = .5*(-Vinf + sqrt(Vinf^2 + 2*TR/(rho*pi*R^2)));
% ------------------------------------------------------------------
```

```
% Streamtube's radius rt calculated via the continuity
A = pi*R^2;
const = (Vinf + w0)*A;
rt = sqrt(const/(Vinf*pi));
% ------------------------------------------------------------------------
% Radial velocity component induced by the rotor at c/4
cquarter=1/4;
viRquarter = -.5*rt*w0*R^2/((R^2+cquarter^2)^1.5);
% ------------------------------------------------------------------------
% Thrust component due to the shroud
TS = -rho*viRquarter*Gamma*pi*Dquarter;
% ------------------------------------------------------------------------
% Total thrust
T = TR + TS;
% ------------------------------------------------------------------------
end
```

Listing 6: Function `ducted_prop_thrust.m`

Listings

References

[1] Tognaccini Renato. *Lezioni di Aerodinamica dell'ala rotante*. Università degli Studi Ferico II, 2020.