Task 4 - Compressor Map

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Overview

This folder contains the code for designing a row of the Compressor map for the Axial Compressor. This task is full of tables, which will be broken down into detail down below.

`task4_main.py` is the main file which calls the other files and runs the code. Readers are to run this code to perfom the analysis.

`Table2.1.csv` contains the data from Table 2.1 in Dr. Cizmas' notes. This data is used to calculate the values for the compressor map. This table is read in by `task4_main.py` and is used to calculate the values for the compressor map. Table 2.1 is shown below:

$\bar{n}$	0.5	0.6	0.7	0.8	0.9	1.0	1.05	1.1
$\bar{\eta_{base}}$	0.9	0.924	0.955	0.97	1.0	1.0	0.98	0.975
$\bar{\dot{m_{base}}}$	0.37	0.47	0.58	0.714	0.86	1.0	1.02	1.04
$\bar{\pi_{base}}$	0.47	0.51	0.59	0.7	0.82	1.0	1.1	1.2

Where;

$$\bar{n} = \frac{n}{n_{ref}}$$
$$\bar{\eta_{base}} = \frac{\eta_{base}}{\eta_{ref}}$$
$$\bar{\dot{m_{base}}} = \frac{\dot{m_{base}}}{\dot{m_{ref}}}$$
$$\bar{\pi_{base}} = \frac{\pi^*_{base}}{\pi^*_{ref}}$$

`Table2.3.csv` contains the data from Table 2.3 in Dr. Cizmas' notes. This data is used to calculate the values for the compressor map. This table is read in by `task4_main.py` and is used to calculate the values for the compressor map. Table 2.3 is shown below:

$\frac{\bar{C_a}}{C_{a_{base}}}$	0.8	0.9	1.0	1.1	1.2
$\frac{\eta}{\eta_{base}}$	0.92	0.98	1	0.97	0.88
$\frac{w}{w_{base}}$	1.25	1.12	1	0.9	0.82

Where;

$$w = \frac{h_1^*}{\eta}(\pi^{*\frac{\gamma-1}{\gamma}} - 1)$$
$$h_1^* = \frac{w\eta}{\pi^{*\frac{\gamma-1}{\gamma}} - 1}$$

Similarly we can say,

$$h_1^* = \frac{w_{base}\eta_{base}}{(\pi^{*\frac{\gamma-1}{\gamma}})_{base} - 1}$$

Making use of these equations, we can write the following:

$$\pi^* = \left[1 + ((\pi^{*\frac{\gamma-1}{\gamma}})_{base} - 1)\frac{w\eta}{w_{base}\eta_{base}}\right]^{\frac{\gamma}{\gamma-1}}$$

`steps.py` contains the 4 different steps that Dr. Cizmas has outlined in his notes. The steps are as follows:

1. Calculate $\pi^* = \pi^*(\bar{n}, \frac{\bar{C_a}}{C_{a_{base}}})$ and $\frac{\pi^*}{\pi^*_{base} = f(\bar{n}, \frac{\bar{C_a}}{C_{a_{base}}})}$, where where $\bar{n} \in (0.5, 1.1)$ and $\frac{\bar{C_a}}{C_{abase}} \in (0.8, 1.2)$ producing a table as shown in Table 2.4.1 and Table 2.4.2. (Tables are in `Table_2_4_1.csv` and `Table_2_4_2.csv` respectively)

$\frac{\bar{C_a}}{C_{a_{base}}}$	0.8	0.9	1.0	1.1	1.2	$\bar{n}$
π^*	4.64045	4.38299	3.93091	3.39379	2.83897	0.5
π^*	5.07483	4.78063	4.26545	3.65607	3.03024	0.6
π^*	5.95028	5.57996	4.93454	4.17687	3.40661	0.7
π^*	7.16637	6.68649	5.85454	4.88616	3.91291	0.8
π^*	8.50639	7.90169	6.85818	5.65264	4.45332	0.9
π^*	10.5374	9.73710	8.36364	6.79104	5.24562	1.0
π^*	11.6748	10.7622	9.19999	7.41866	5.67803	1.05
π^*	12.8177	11.7906	10.0363	8.04337	6.10576	1.1

$\frac{\bar{C_a}}{C_{a_{base}}}$	0.8	0.9	1.0	1.1	1.2	$\bar{n}$
$\frac{\bar{\pi^*}}{\pi^*_{base}}$	1.18050	1.11501	0.99999	0.86336	0.72222	0.5
$\frac{\bar{\pi^*}}{\pi^*_{base}}$	1.18975	1.12078	0.99999	0.85713	0.71042	0.6
$\frac{\bar{\pi^*}}{\pi^*_{base}}$	1.20584	1.13079	1.0	0.84646	0.69036	0.7
$\frac{\bar{\pi^*}}{\pi^*_{base}}$	1.22407	1.14210	0.99999	0.83459	0.66835	0.8
$\frac{\bar{\pi^*}}{\pi^*_{base}}$	1.24033	1.15215	0.99999	0.82422	0.64934	0.9
$\frac{\bar{\pi^*}}{\pi^*_{base}}$	1.25991	1.16422	1.0	0.81197	0.62719	1.0
$\frac{\bar{\pi^*}}{\pi^*_{base}}$	1.26899	1.16980	0.99999	0.80638	0.617177	1.05
$\frac{\bar{\pi^*}}{\pi^*_{base}}$	1.27712	1.17479	0.99999	0.80142	0.608364	1.1

2. Calculate $\frac{\bar{\dot{m}}}{\dot{m}_{base}} = f(\bar{n}, \frac{\bar{C_a}}{C_{a_{base}}})$, by making use of:

$$\frac{\bar{\dot{m}}}{\dot{m}_{base}} = \frac{\bar{C_a}}{C_{a_{base}}} \left[\frac{\bar{\pi^*}}{\pi^*_{base}} \right]^{\frac{1}{3}}$$

Similar to step 1. Table 2.5 is produced. (Table is in `Table_2_5_csv`)

$\frac{\bar{C_a}}{C_{a_{base}}}$	0.8	0.9	1.0	1.1	1.2	$\bar{n}$
$\frac{\bar{\dot{m}}}{\dot{m}_{base}}$	0.84549	0.93326	1.0	1.04743	1.07664	0.5
$\frac{\bar{\dot{m}}}{\dot{m}_{base}}$	0.84769	0.93487	0.99999	1.04490	1.07074	0.6
$\frac{\bar{\dot{m}}}{\dot{m}_{base}}$	0.85150	0.93764	1.0	1.04054	1.06057	0.7
$\frac{\bar{\dot{m}}}{\dot{m}_{base}}$	0.85577	0.94076	0.99999	1.03566	1.04918	0.8
$\frac{\bar{\dot{m}}}{\dot{m}_{base}}$	0.85955	0.94351	1.0	1.03135	1.03914	0.9
$\frac{\bar{\dot{m}}}{\dot{m}_{base}}$	0.86404	0.94679	1.0	1.02622	1.02718	1.0
$\frac{\bar{\dot{m}}}{\dot{m}_{base}}$	0.86612	0.94830	0.99999	1.02386	1.02169	1.05
$\frac{\bar{\dot{m}}}{\dot{m}_{base}}$	0.86796	0.94965	0.99999	1.02175	1.01680	1.1

3. Calculate $\bar{\pi} = \bar{\pi}(\bar{n}, \frac{\bar{C_a}}{C_{a_{base}}})$ and $\bar{\dot{m}} = \bar{\dot{m}}(\bar{n}, \frac{\bar{C_a}}{C_{a_{base}}})$, by making use of:

$$\bar{\pi} = \bar{\pi_{base}} \frac{\pi^*}{\pi^*_{base}}$$

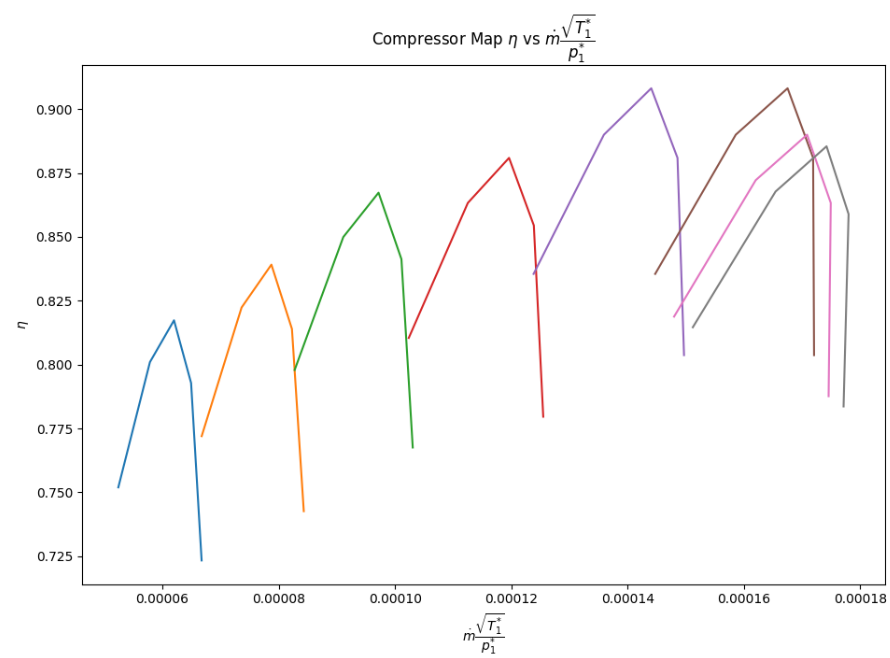
   Where $\bar{pi_{base}}$ comes from `Table2.1.csv` and $\frac{\pi^*}{\pi^*_{base}}$ comes from `Table_2_4_2.csv`. Similarly,

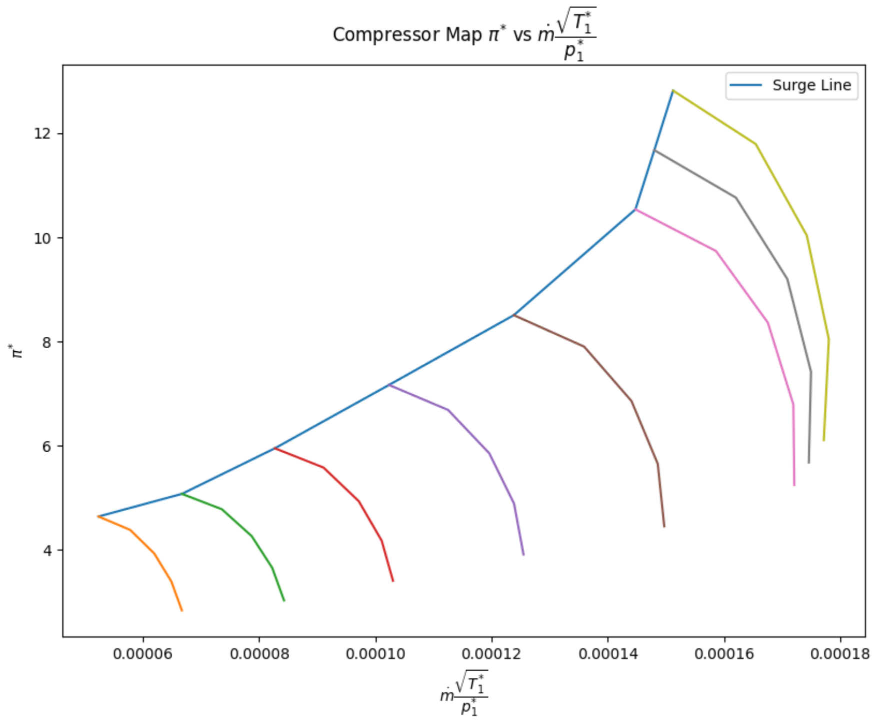
$$\bar{\dot{m}} = \bar{\dot{m_{base}}} \frac{\bar{\dot{m}}}{\bar{\dot{m_{base}}}}$$

   Where $\bar{\dot{m_{base}}}$ comes from `Table2.1.csv` and $\frac{\bar{\dot{m}}}{\bar{\dot{m_{base}}}}$ comes from `Table_2_5.csv`.

4. Calculate $\eta = \eta(\bar{n}, \frac{\bar{C_a}}{C_{a_{base}}})$ using tables `Table2.1.csv`, `Table2.3.csv`.

5. Lastly we are to draw the Compressor map, with axes of $\dot{m}\frac{\sqrt{T_1^*}}{p_1^*}$, π^* and η. The map is drawn:





Compressor Map π^* vs $\dot{m}\frac{\sqrt{T_1^*}}{p_1^*}$
Surge Line
12
10
8
6
4
π^*
0.00006
0.00008
0.00010
0.00012
0.00014
0.00016
0.00018
$\dot{m}\frac{\sqrt{T_1^*}}{p_1^*}$