Turbomachinery: Compressor preliminary design

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1. Problem Description
2. Similitude
3. Blade Modeling
4. Efficiency
5. CFD
6. References

Initial Conditions & Constraints

Inlet conditions

- $P_{T0} = 1 bar$
- $T_{T0} = 300 K$

Constraints

- $r_{max} = 0.45 m$
- $\beta_{TT} = 1.45$
- $\dot{Q} = 100 \frac{kg}{s}$
- **max** η

Due to the **course track** and **preference**, the turbomachinery design will be on an **axial** compressor.

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1. Problem Description
2. Similitude
   - Procedural Steps
   - Main Design Quantities
   - $V_{t_{mean}}$, $V_{a_{mean}}$, U_{mean} & velocity triangles
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Procedural Steps

Hypothesis

It has been chosen to not use an **inlet guide vane** for simplicity of design and so $V_{t0} = 0\frac{m}{s}$ and χ dictate the behaviour of λ. Another initial desing choice is to keep, in the similarity/adimensional analysis of the compressor, V_a **constant** and to **avoid** using a **flaring based** approach.

Main procedural steps:

- λ and ψ computation from χ and V_{t0}
- ϕ and η computation
- V_a and L_{eu} computation from ϕ, β_{TT} and η
- computing **mean** velocity triangles, using the above hypothesis
- computing **blade height**

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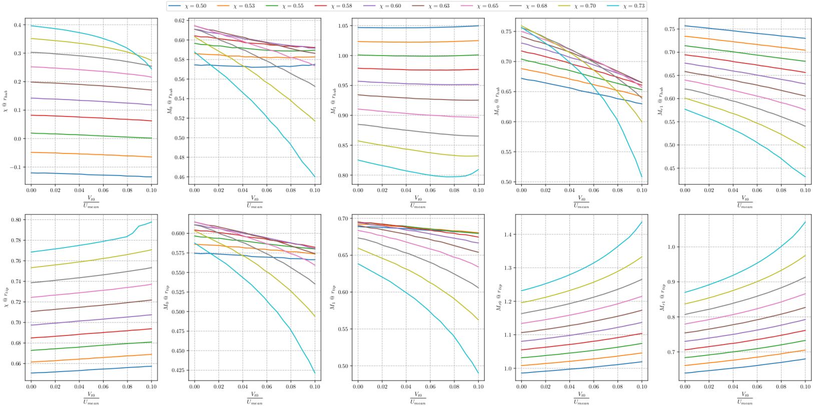
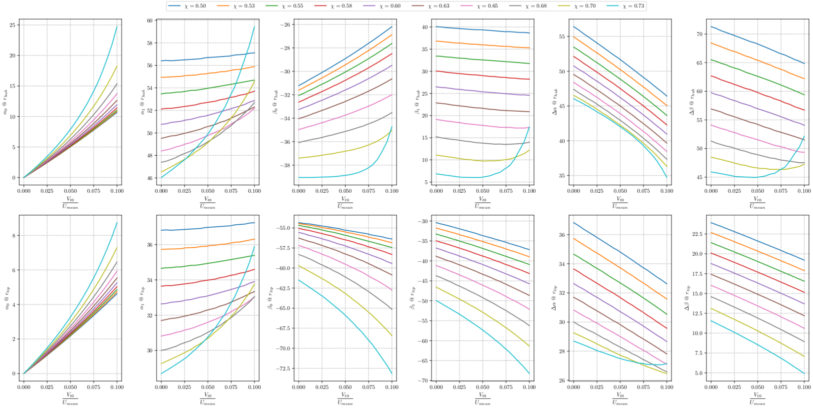
Graph Analysis: χ & M



Graph Analysis: α & β



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λ & ψ

From the previous graphs:

- $\chi = 0.55$
- $r_{mean} = 0.325m$
- $\frac{V_t}{U_{mean}} = 0$

Taking into account the previous modeling hypothesis:

$$\lambda = (1 - \chi - \frac{V_t}{U_{mean}}) \cdot 4 \tag{1}$$

$$\psi = \frac{\lambda}{2} \tag{2}$$

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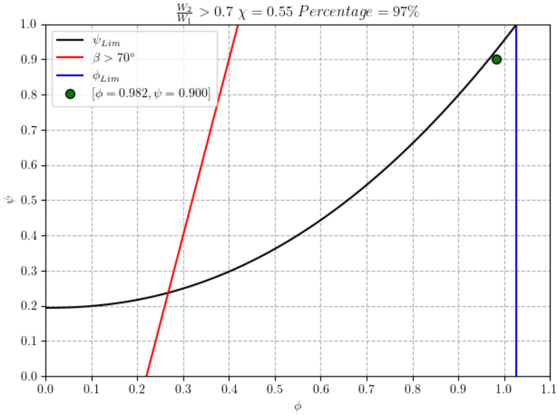
$\phi(\psi)$

From [?, Sec. 10.4] it is imposed that $\frac{W_2}{W_1} \geq 0.7$ with a *safety* margin of 2%.



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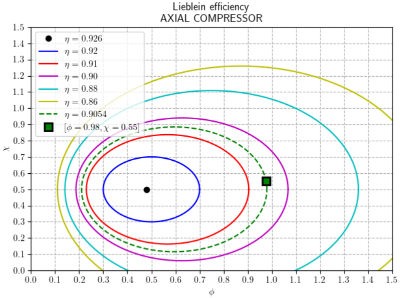
η & L_{eu}

η is computed from an **Lieblein** efficiency chart[1] given ϕ and χ. This parameter will be used for the computation of L_{eu} given the β_{TT} target.



$$L_{is} = \frac{\gamma \; R}{\gamma - 1} \; T_{in} \; (\beta_{TT}^{\frac{\gamma-1}{\gamma}} - 1) \tag{3}$$

$$L_{eu} = \frac{L_{is}}{\eta} \tag{4}$$

[1] This chart has been interpolated from the course slides charts.

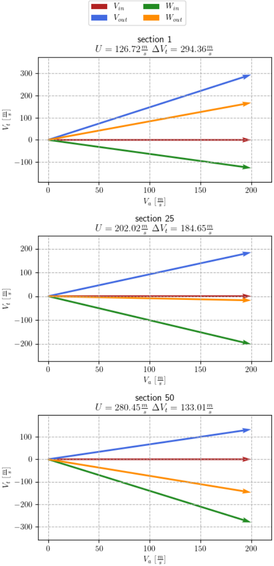
$$U_{mean} = \frac{L_{eu}}{\psi} \tag{5}$$

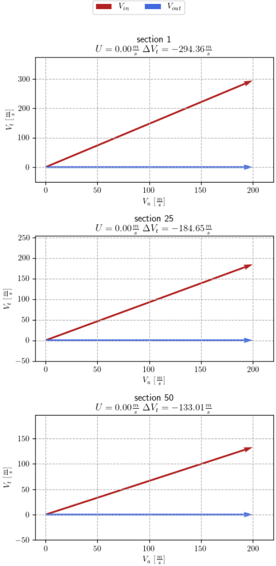
$$V_{a_{mean}} = \phi \; U_{mean} \tag{6}$$

$$L_{eu} = U_1 \; V_{t1} - U_0 \; V_{t0} \tag{7}$$

$$= U_{1_{mean}} \; V_{t1_{mean}} - U_{0_{mean}} \; V_{t0_{mean}} = U_{mean} \, \Delta V_{t_{mean}} \tag{8}$$

ΔV_t computation allows to get a *first sketch* of the **velocity triangles**. The first analysis results are stored in `compressor_0.55_0.325_28_28.txt`.


V_{in} W_{in}
V_{out} W_{out}
section 1
$U = 126.72\frac{m}{s}$ $\Delta V_t = 294.36\frac{m}{s}$
section 25
$U = 202.02\frac{m}{s}$ $\Delta V_t = 184.65\frac{m}{s}$
section 50
$U = 280.45\frac{m}{s}$ $\Delta V_t = 133.01\frac{m}{s}$
$V_t\ [\frac{m}{s}]$
$V_a\ [\frac{m}{s}]$


V_{in} V_{out}
section 1
$U = 0.00\frac{m}{s}$ $\Delta V_t = -294.36\frac{m}{s}$
section 25
$U = 0.00\frac{m}{s}$ $\Delta V_t = -184.65\frac{m}{s}$
section 50
$U = 0.00\frac{m}{s}$ $\Delta V_t = -133.01\frac{m}{s}$
$V_t\ [\frac{m}{s}]$
$V_a\ [\frac{m}{s}]$

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Profile Losses

The profile losses used are related to the **Leiblein modeling** approach, [**?**, Ch. 6].

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Thank you!

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