Measurement of the rotor wake using PIV on a scaled turbine rotor in a water flume

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Measurement of the rotor wake using PIV on a scaled turbine rotor in a water flume

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Motivation to this study is the incomprehensible wake!

An alternative presentation of the wake: near wake – far wake – turbulent wake
The next motivation is to study of the wake behind Glauert rotor.

*Wake behind Joukowsky rotor - I*

*Wake behind Betz rotor - II*

*What is a wake behind Glauert rotor?*

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Flume

• $V_0 = 0.38$ and $0.5$
ROTOR
The current study is turbine by Glauert opt. for $\lambda=5$

- $D=0.35\text{m}$
- SD7003 aerofoil
- $Re=20\ 000$
- $V_0=0.38\text{ and }0.5$
Measurement of the power and trust
Measurement of the blade circulation
Circulation

\[ \Gamma = \oint \vec{u} \cdot d\vec{l} \]
Blade circulation \( \lambda = 5 \)

Circulation

\[ \Gamma = \oint \mathbf{u} \cdot d\mathbf{l} \]

\[ \frac{\Gamma}{2\pi U_\infty R} \]

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Blade circulation \( \lambda = 7 \)

Circulation

\[
\Gamma = \oint \vec{u} \cdot d\vec{l}
\]

\[
\frac{\Gamma}{2\pi U_\infty R}
\]
Sketch of the setup with stereoscopic PIV

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New motivation is to extend a domain of the PIV investigation

Sketch of 12 testing windows of the current experiment

Sketch of the windows in the “MEXICO” PIV-experiment

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Visualizations of WT’s wake TSR=6
Visualizations of WT’s wake for different TSR

$\lambda = 4$

$\lambda = 5$

$\lambda = 6$

$\lambda = 7$

$\lambda = 8$
Tip vortex structure, unfolded, 0, 15, 30, 45, 60, 75, 90, 105 deg

\[ \lambda = 4 \]
\[ \lambda = 5 \]
\[ \lambda = 6 \]
\[ \lambda = 7 \]
Axial velocity, TSR=6, 100 images

\[ \lambda = 5 \]

\[ U_{ax.} \]

Vorticity
Instantaneous location of vortex center
0,15, 30,45,60,75,90,105 deg

λ=4

λ=5

λ=6

λ=7
Tip vortex and vectors, TSR=6
Tip vortex – vorticity, phase averaged, TSR=3-7

\(\lambda = 3\)

\(\lambda = 4\)

\(\lambda = 5\)

\(\lambda = 6\)

\(\lambda = 7\)
Axial velocity, phase averaged, TSR = 3-5

\( \lambda = 3 \)

\( \lambda = 4 \)

\( \lambda = 5 \)

\( \lambda = 6 \)

\( \lambda = 7 \)
Mean Axial Velocity U, TSR 4-7
Axial velocity, U rms

λ = 3

λ = 4

λ = 5

λ = 6

λ = 7
Tangentiel Vel, W-mean TSR 4-7
LDA prediction of wake frequencies
LDA prediction of wake frequencies
Experimental investigation of the rotor by Glauert Opt. of TSR = 5 was made at TSR 3-8:

- Power and thrust coefficients
- Circulation along blade
- Visualization captures dynamics of helical structures
- PIV-mapping of the flow in the wake
- LDA measurements - frequencies

Summary

The wake pitch keeps a constant in axial direction
The wake expansion coincide with the prediction of the actuator disk theory
The far wake with double of the axial factor may be indicated before the wake breakdown
Characteristic frequencies in the wake: blade, rotor and Strouhal
The wake breakdown with a reduction of the axial factor displays under small Re = 20000 too

Conclusions