DESIGN AND NUMERICAL ANALYSIS OF THE PROCESSES IN SILOXANE VAPOR DRIVEN TURBINE

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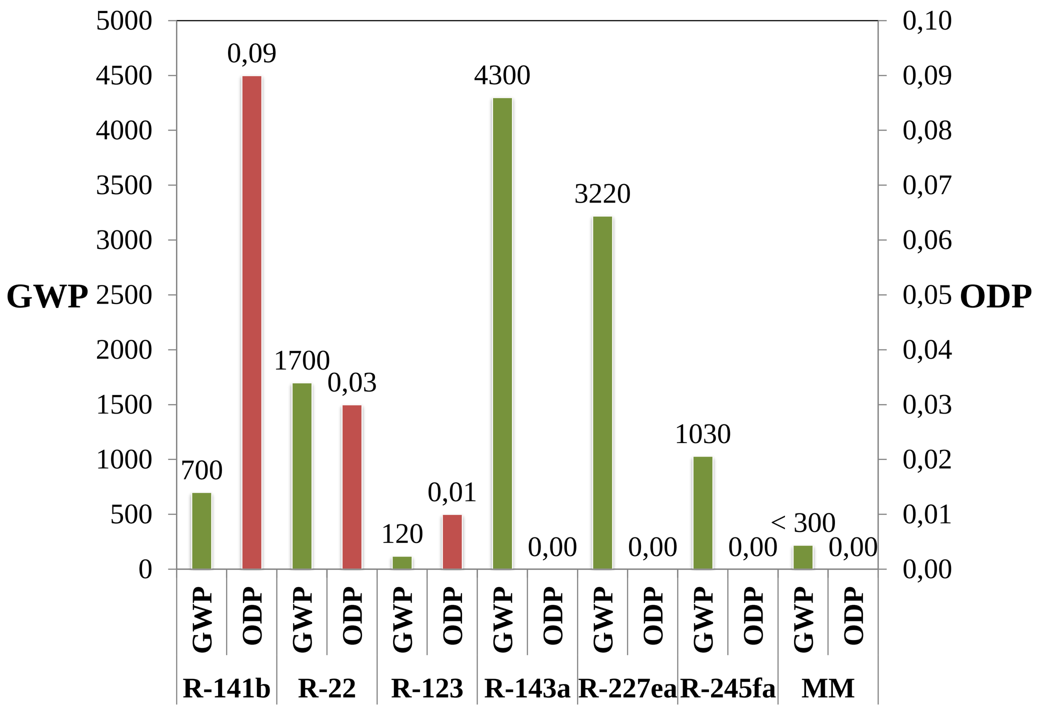
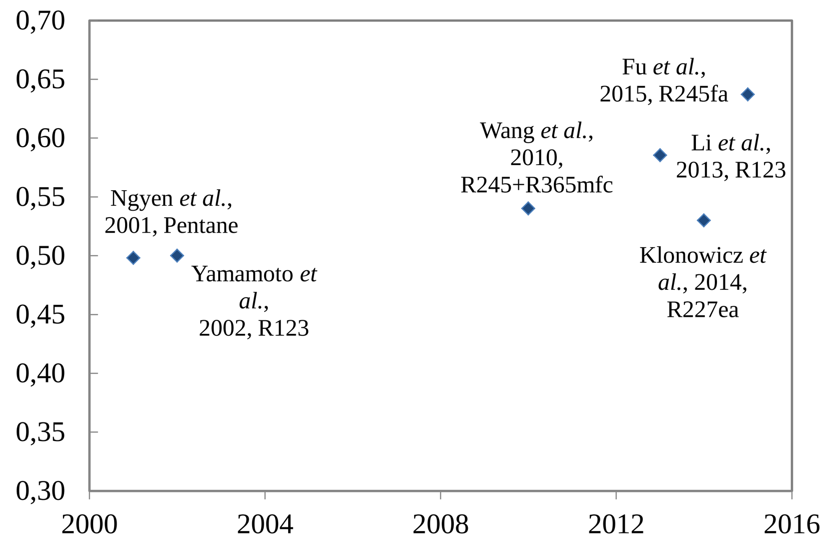
Motivation

One of the most important questions in the designing process of a recovery plant for waste heat recovery is the choosing of a working fluid. Nowadays the aspects of using of various hydrocarbons, freons and alcohols in ORC are widely researched by different authors.

Modern requirements for environment safety determine ozone depletion potential (ODP) and global warming potential (GWP) as main criteria for choosing of a working fluid. In this case the most promising alternatives to different hydrocarbons, freons and alcohols are zeotropic mixtures and siloxanes.

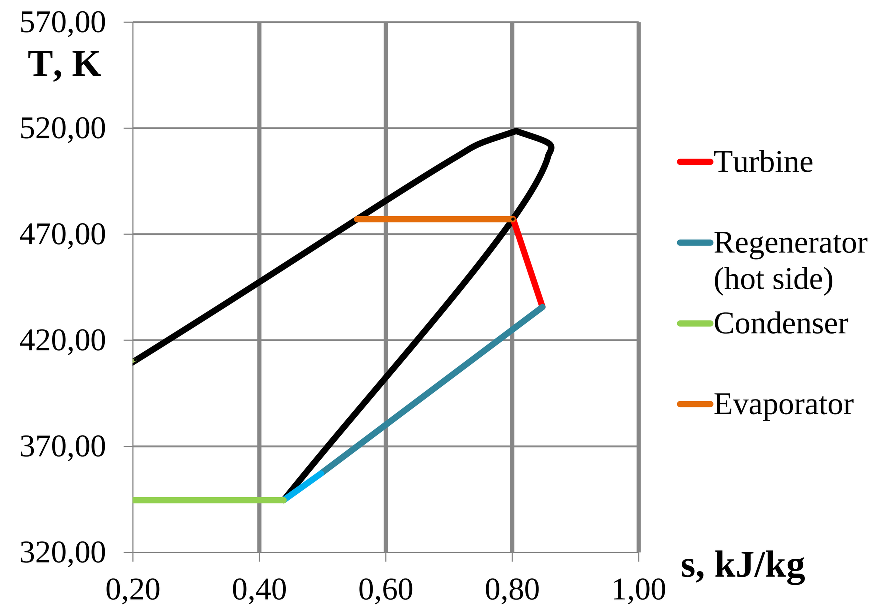


- Significant peculiarities in details of the expansion process in the ORC turbines
- No investigations of the fluid flow highlights in the siloxane vapor driven turbines



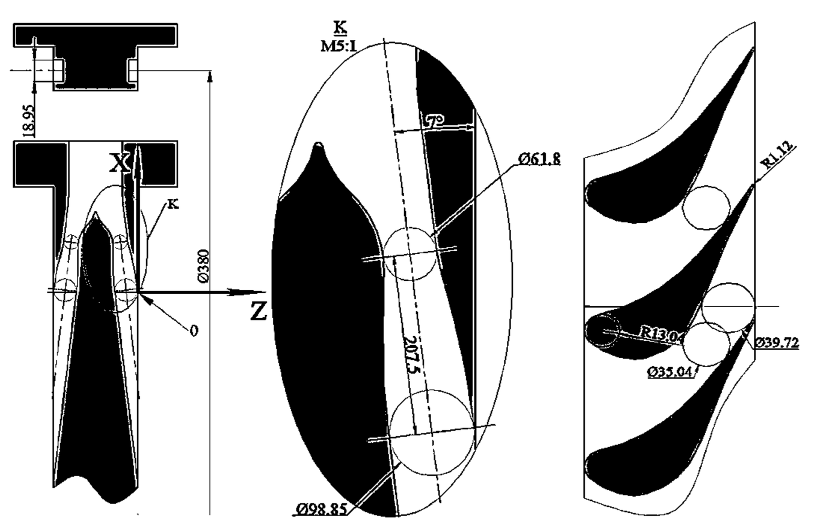
Investigation object

- Subcritical ORC with hexametyldisiloxane



- High enthalpy drop supersonic turbine

Parameter	Dimensions	Value	Parameter	Dimensions	Value
D_m	**mm**	**380**	**α_1**	**deg.**	**7,00**
n	rev/min	12000	ΔL_{ax}	mm	7,00
H_0	kJ/kg	66,26	ΔL_{tc}	mm	0,30
G	**kg/s**	**6,86**	β_1	deg.	90,00
C_{ax}/u	**-**	**1,52**	Z_2	-	55
ε	-	0,97	**l_2**	**mm**	**24,75**
Z_1	-	7	β_2^*	deg.	30,00
l_1	**mm**	**18,95**	Ω	deg.	60,00



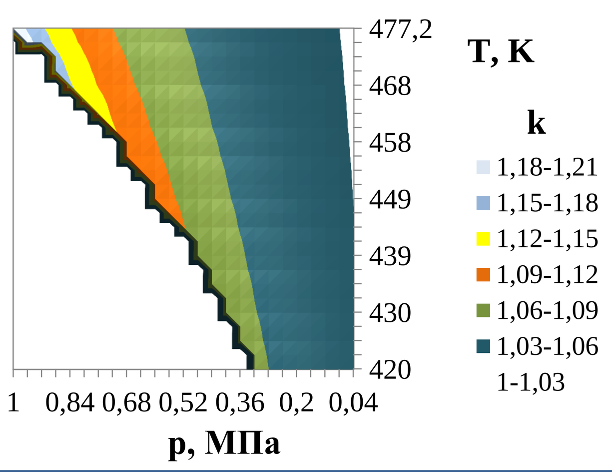
Numerical model

- Real gas model using Aungier Redlich-Kwong equation of state and Rigid Non Interacting Sphere model:

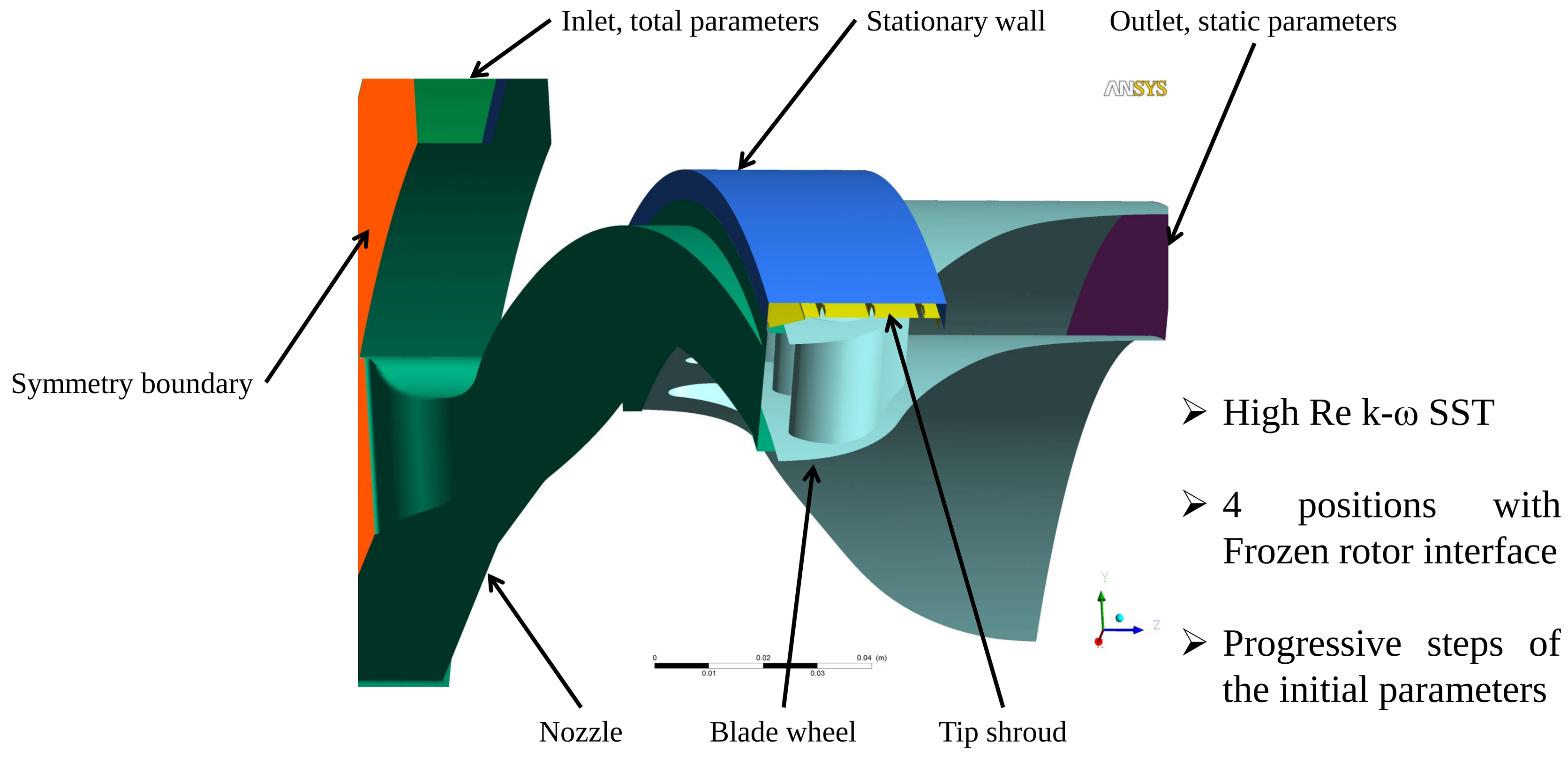
$$p=\frac{RT}{\nu-b+c}-\frac{a(T)}{\nu(\nu+b)};\qquad a=a_0\left(\frac{T}{T_c}\right)^{-0,5};\qquad c=\frac{RT_c}{p_c+\dfrac{a_0}{\nu_c(\nu_c+b)}}+b-\nu_c$$

$$\frac{c_p^0}{R}=a_1+a_2T+a_3T^2+a_4T^3+a_5T^4;$$

$$\mu=26{,}69\frac{\sqrt{wT}}{\Omega(T)\sigma^2}$$



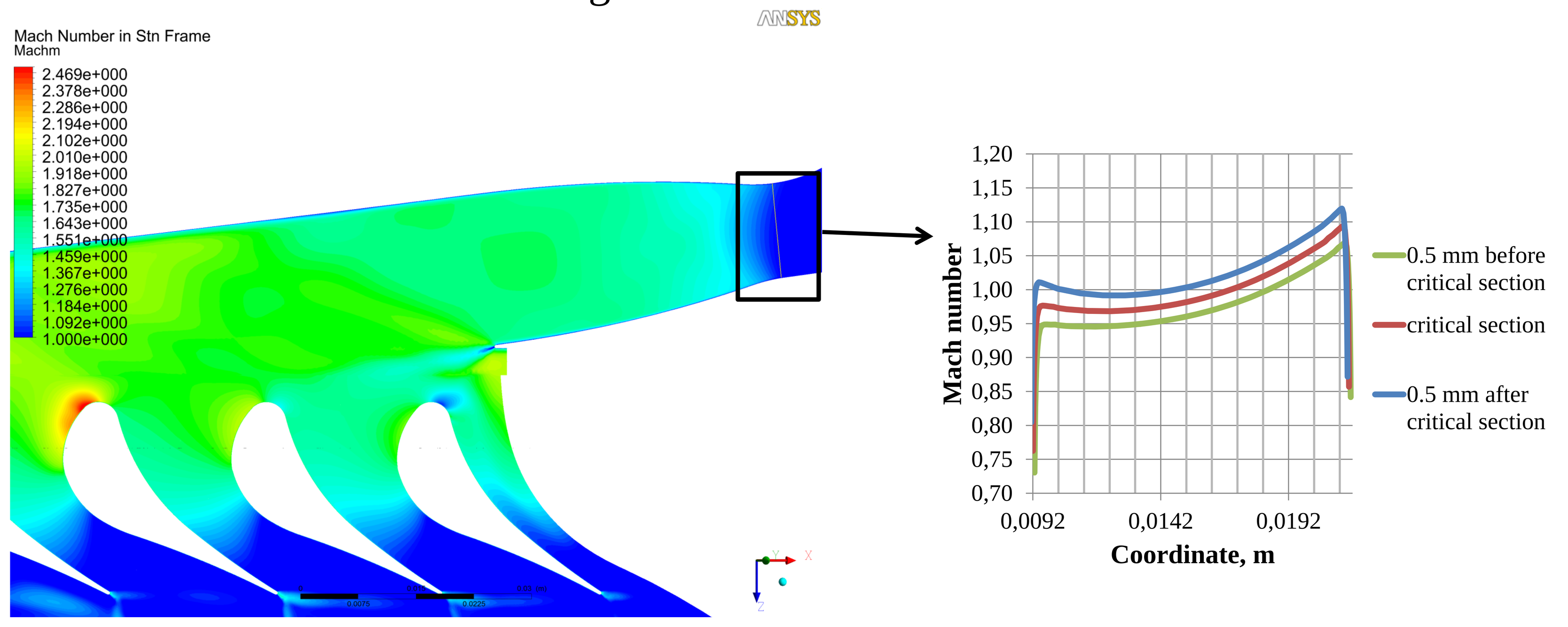
Numerical model



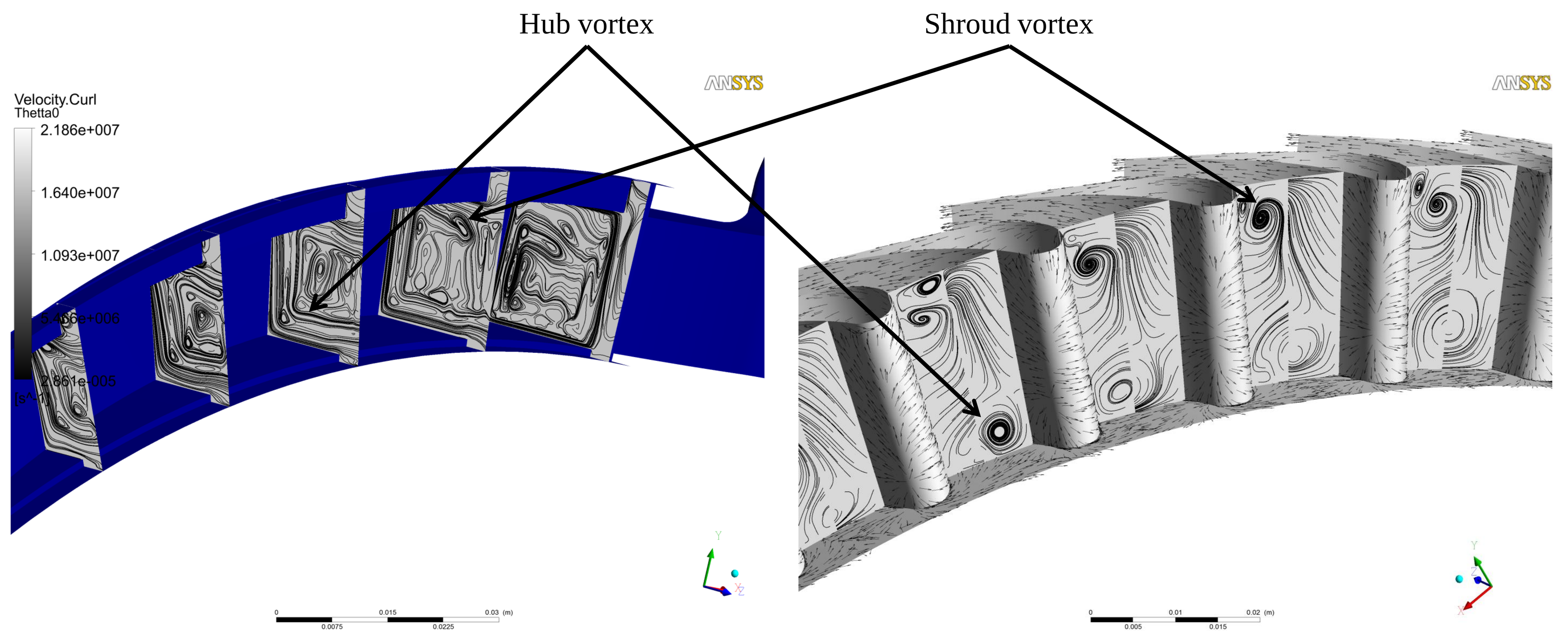
- High Re k-ω SST
- 4 positions with Frozen rotor interface
- Progressive steps of the initial parameters

Results

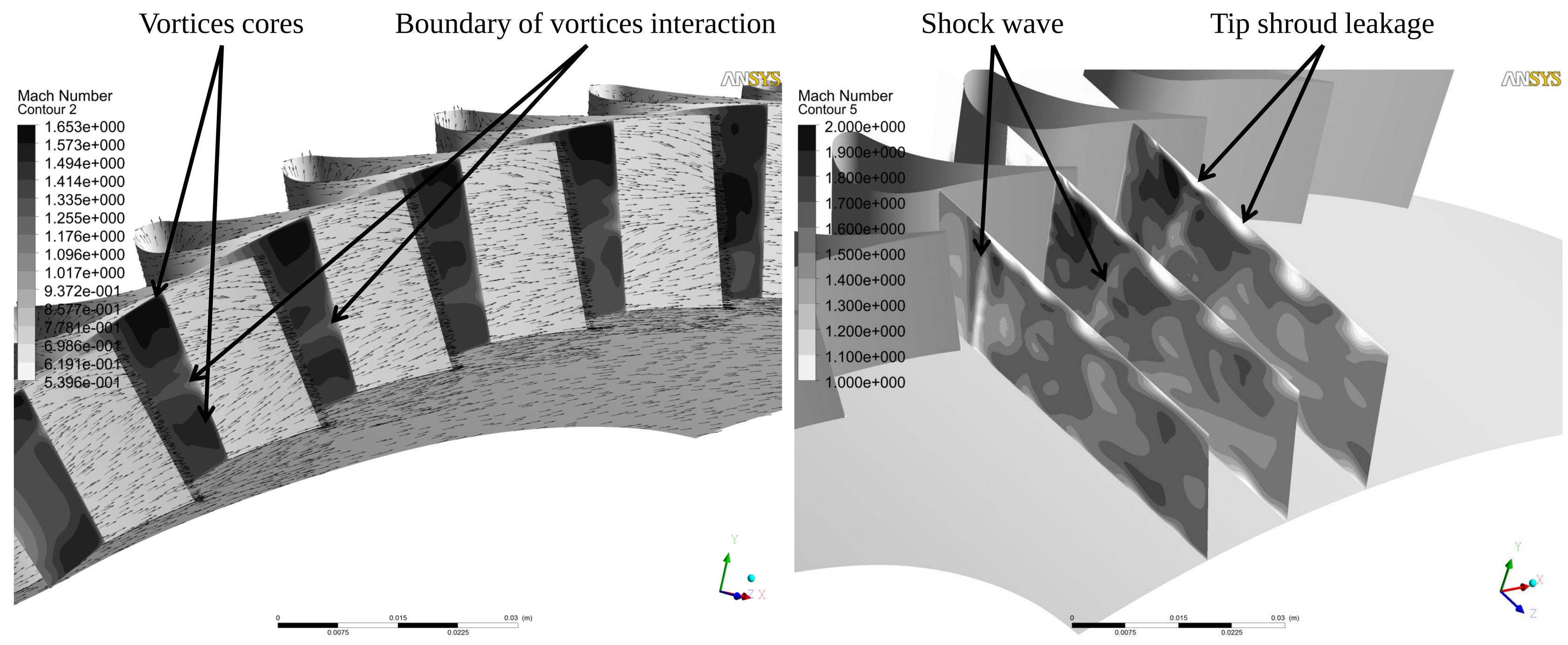
- The flow in the critical section is not fully supersonic. Physically, it means that the position of real critical section changed to the downstream direction in comparison with its design position. The velocity profile near the critical section is highly distorted towards to the straight nozzle wall



- The double-vortex structure appears in the nozzle and spreads to the bade wheel. The hub vortex rotates clockwise and rests against the blade wheel hub. The shroud vortex has a counterclockwise rotation and rests against the blade wheel shroud because of the inertial forces



- Specific shape of the shock wave after the blade wheel. The intensity of the normal shock wave decreases from hub to shroud. Shroud vortex is underexpanded and continues its expansion after the blade wheel



$$\eta_t=\frac{M_{BW}\cdot\pi\cdot n}{30\cdot G\cdot H_0}=0{,}699\qquad N=\frac{M_{BW}\cdot\pi\cdot n}{30}=309{,}1\,(kW)$$

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