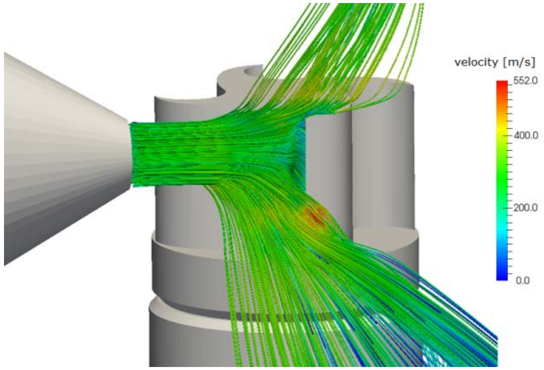
Zürcher Hochschule
für Angewandte Wissenschaften

School of Engineering

IEFE Institut für Energiesysteme
und Fluid-Engineering

HIGH SPEED MICRO TURBINE FOR SPECTROSCOPY APPLICATION



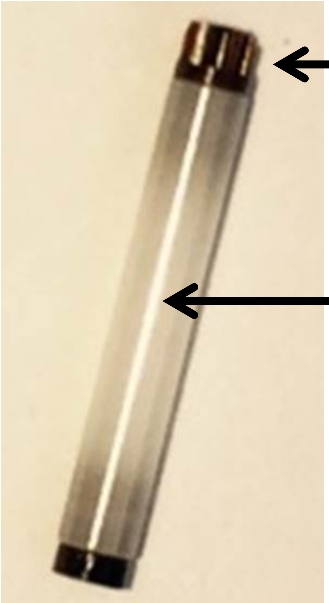
Bruker BioSpin

supported by CTI Swiss

Nicoleta Herzog, Dirk Wilhelm
Zurich University of Applied Sciences

OFW11, 26-30 June 2016

Nuclear Magnetic Resonance (NMR)



turbine cap

rotor

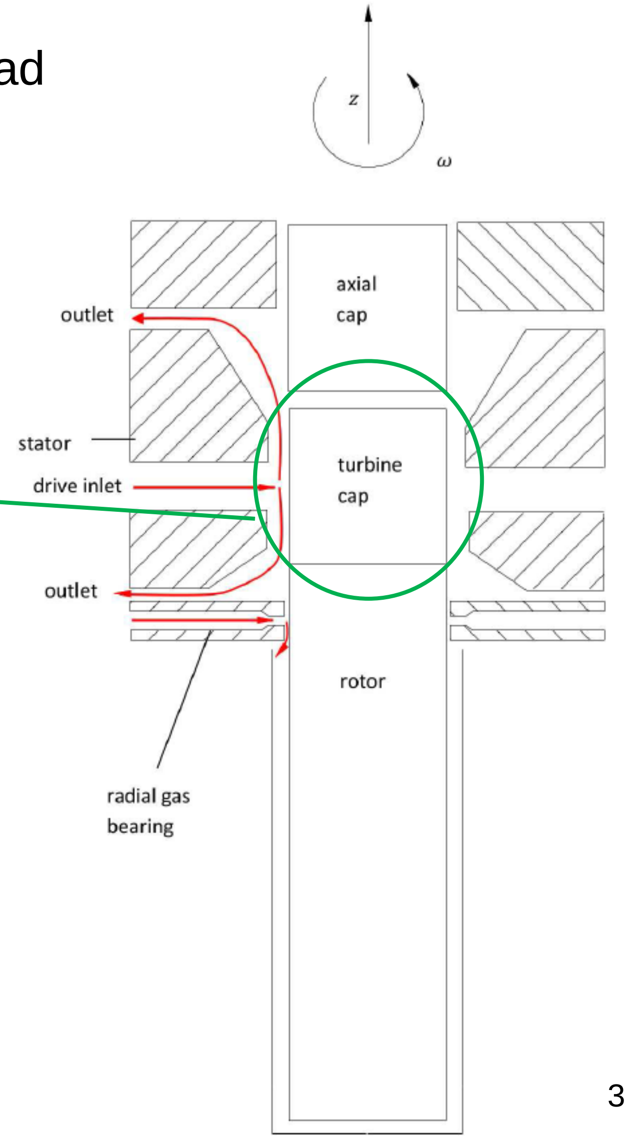
NMR spectrometer

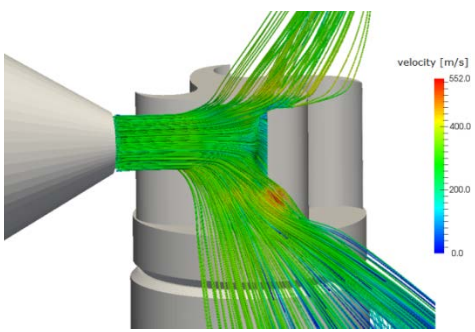
Goal of the project

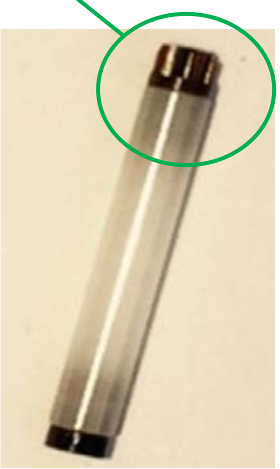
Development of a Magic Angle Spinning (MAS) probe head for Nuclear Magnetic Resonance (NMR) applications

- High rotation speed of up to 120kHz
- Pressurized air at ambient T
- Low temperature T=100K (Nitrogen), T=40K (Helium)

Rotor is driven by a **micro turbine** of 1.3mm or 0.7mm diameter







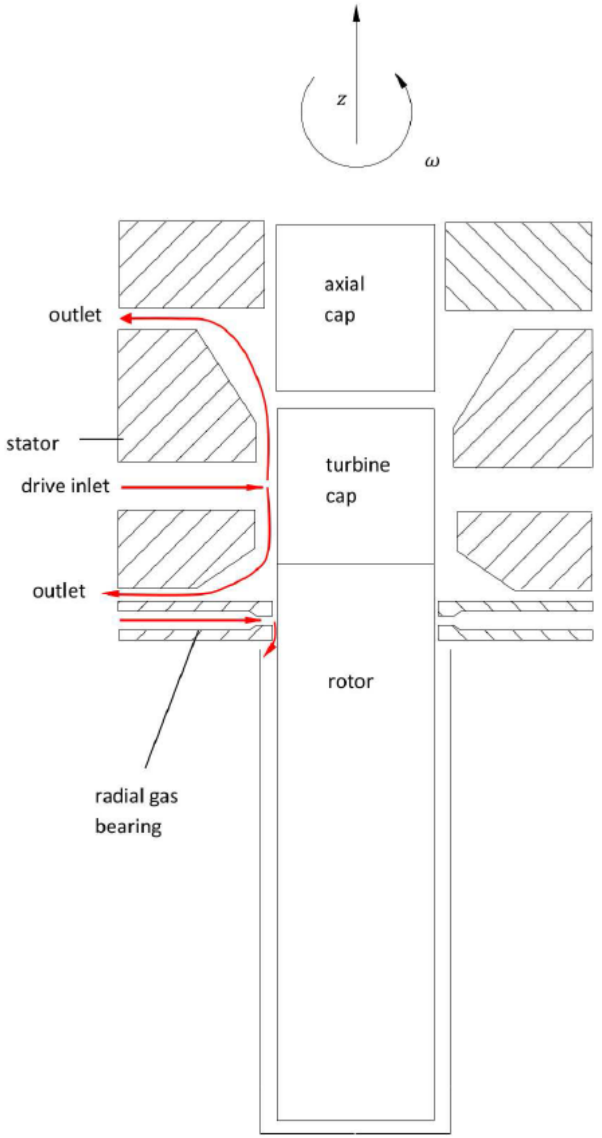
Scientific Innovation

CFD analysis of the MAS rotor stator system

- Rotor diameter 1.3mm
- Spinning rates between 23kHz and 67kHz
- Promoted by air
- Ambient temperature

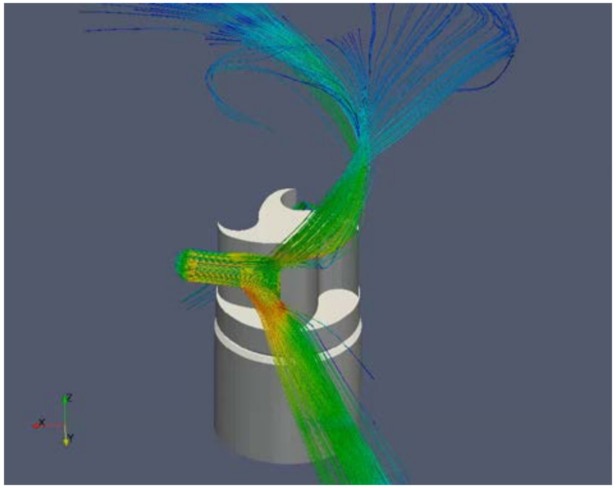
Influence of fabrication tolerances on:

- Forces, driven torques
- Turbine efficiency
- Optimization potential



Simulation Setup

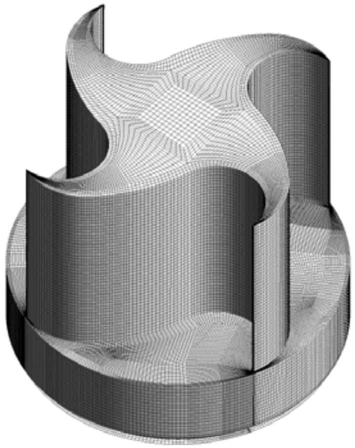
- Ma>0.3 → compressible fluid (air is set as ideal gas)
- Viscosity of gas according to Sutherland-model
- Ambient temperature 20°C
- Ambient pressure 1 bar

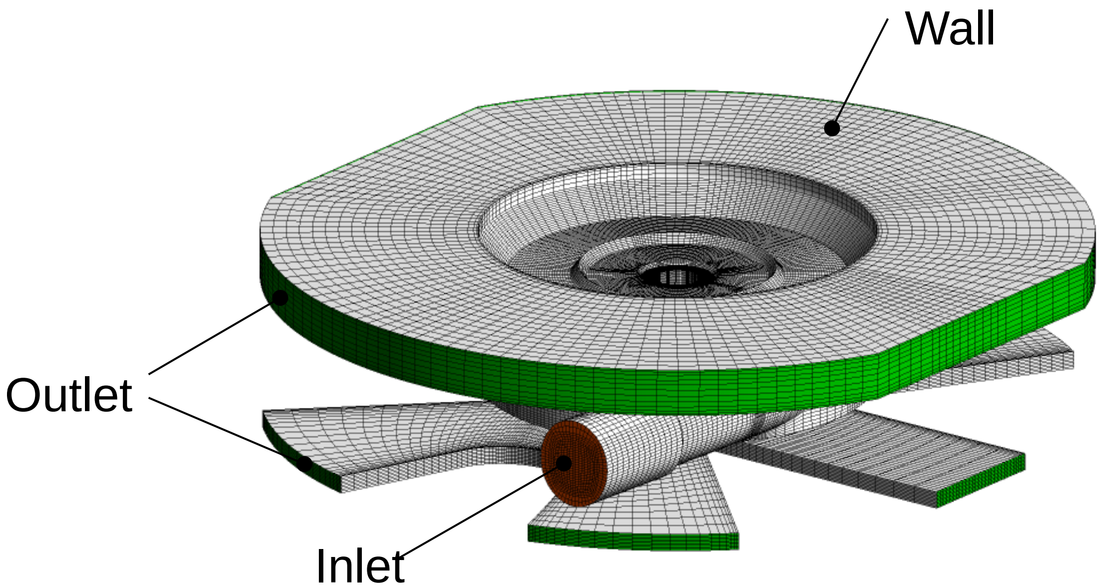


- Stationary operating state: ***rhoSimpleFoam***
- Transient operating state: ***rhoPimpleDyMFoam***

Boundary conditions and mesh

- Inlet: mass flow rate [kg/s]
  ambient temperature 20 °C
- Outlet: ambient pressure 1 bar
- Walls: no-slip, adiabatic
- Rotor: Rotation rate [rad/s]





Total 2'516'117 cells (Hexaedra)

Turbulence Modeling

Reynolds-number at 67kHz

Ort	mag(U) [m/s]	charac. L [m]	Temp [K]	RE
Inlet pipe	21.90	0.00230	293.000	2776.94
Inlet spiral	34.52	0.00200	292.637	3809.54
Nozzle largest area	56.80	0.00115	292.825	3602.84
Nozzle smallest area	263.18	0.00031	258.518	4969.59
Rotor shaft	273.60	0.00130	281.051	20262.88

	M_x		M_y		M_z	
Turbulence model	$Nm \cdot 10^{-5}$	%	$Nm \cdot 10^{-5}$	%	$Nm \cdot 10^{-5}$	%
without	-1.526	0.00	-3.798	0.00	1.564	0.00
k-omega-SST	-1.721	12.78	-3.995	5.19	1.552	-0.77
k-omega-SST-lowRe	-1.726	13.11	-3.990	5.06	1.556	-0.51
v2f	-1.523	-0.20	-3.767	-0.82	1.576	0.77

Re-numbers are in the transition region of laminar and turbulent flow

Driven torque:
small deviation in the use of turbulence models
± 0.77%

=> numerical simulations were performed without turbulence model

Transient Simulation

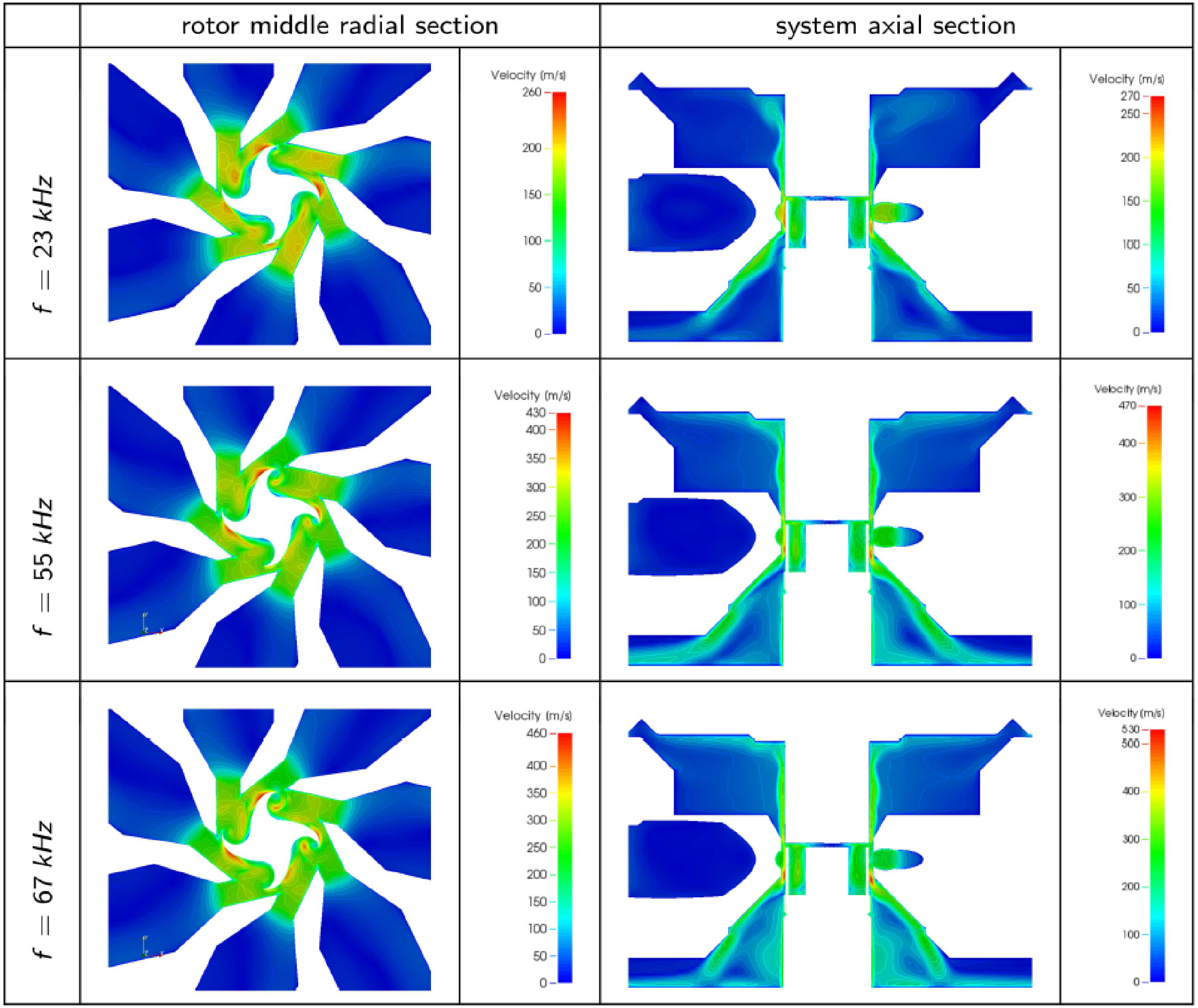
- Rotation rate 23 kHz
- Mass flow rate1.2e-4 kg/s

(a) $\phi = 0°$ (b) $\phi = 30°$ (c) $\phi = 60°$

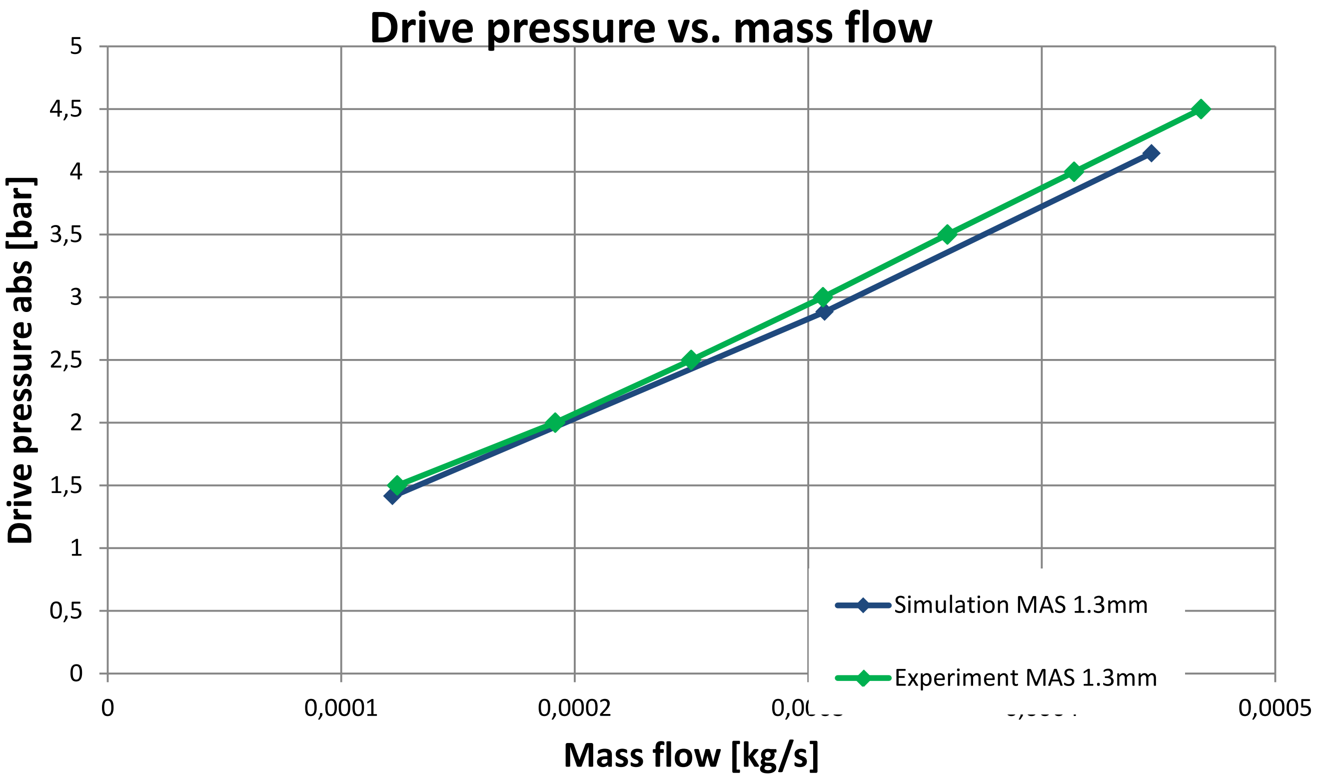
Table 7. Driven torque at $23\,kHz$ rotation frequency for different time settings.

simulation case	M_z $Nm \cdot 10^{-6}$	deviation %
steady-state, initial position $\phi = 0°$	4.597	0.00
steady-state, average over the three ϕ-positions	4.606	0.22
unsteady, time average over one turbine revolution	4.574	-0.50

Velocity field MAS1.3



Comparison with measurements



Optimization criteria

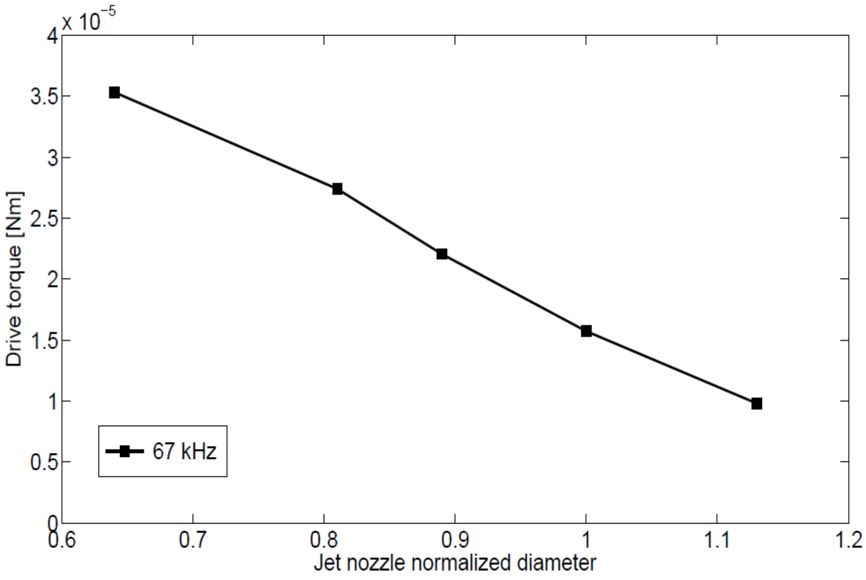
- Not primarily the efficiency
- Achievement of a rotor high speed
- Turbine stability

Sensitivity study in the frame of fabrication tolerances:

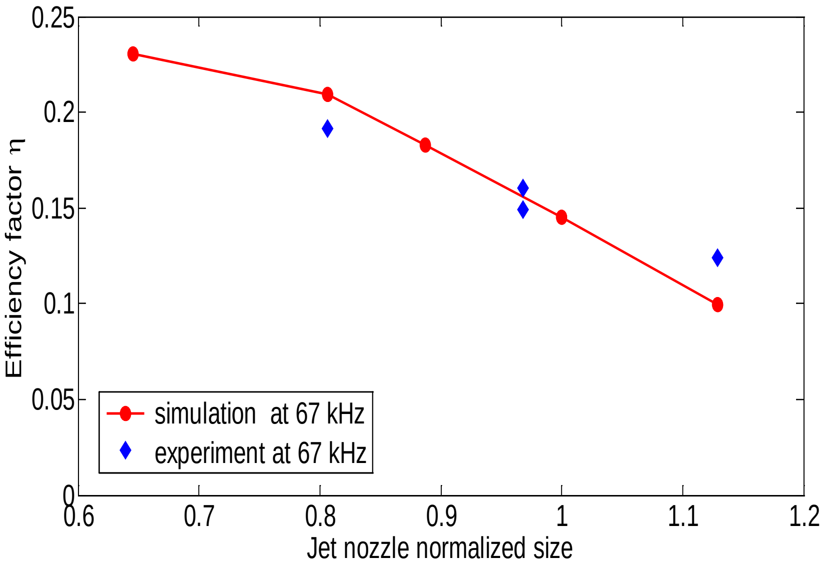
1. Variation of the nozzle position relative to the rotor
2. Variation of the nozzles diameter

Driven torque and efficiency

Driven torque



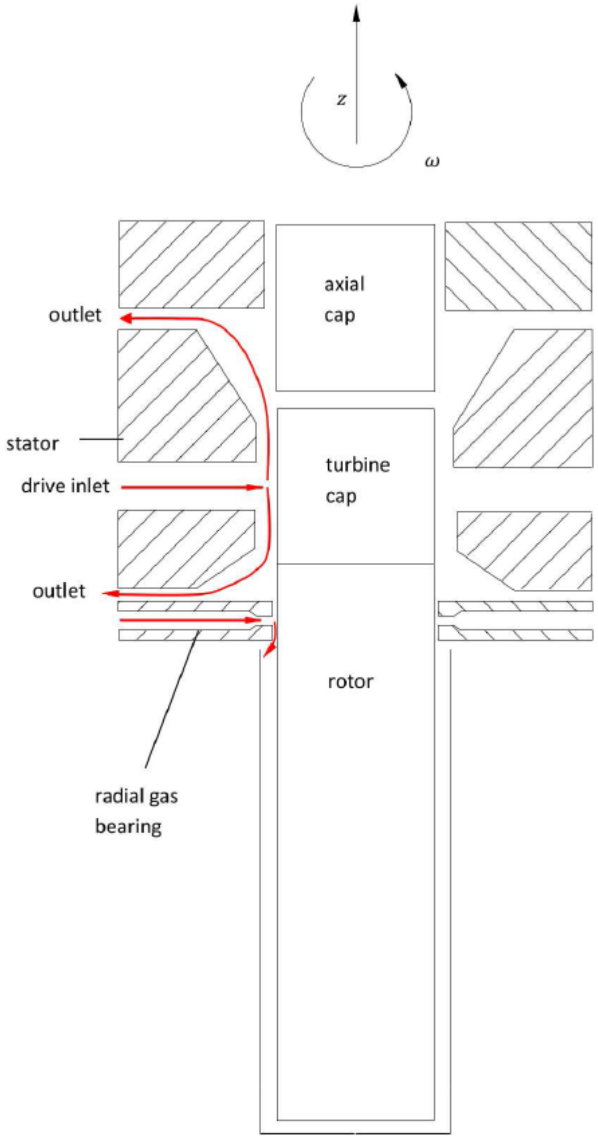
Efficiency factor



Further work

Investigation of the MAS rotor stator system:

- Smaller turbine diameter MAS0.7
- Spinning rates up to 120kHz
- Driven with Nitrogen at 100 K
- Driven with Helium at 40 K
- Gas bearing system



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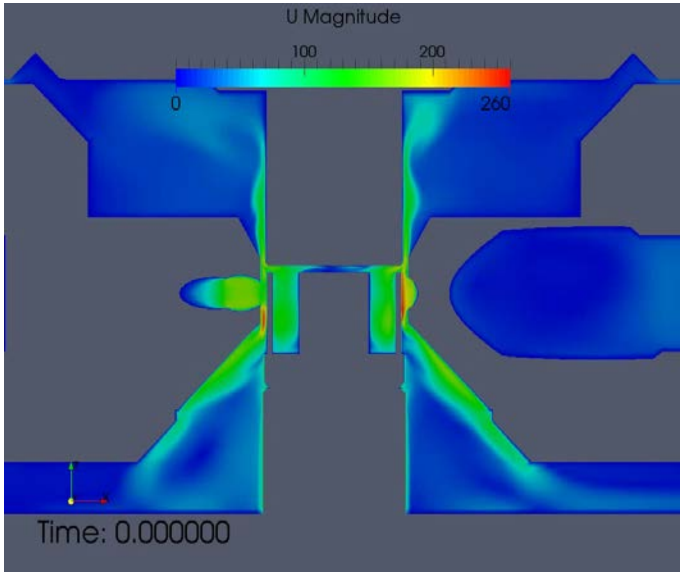

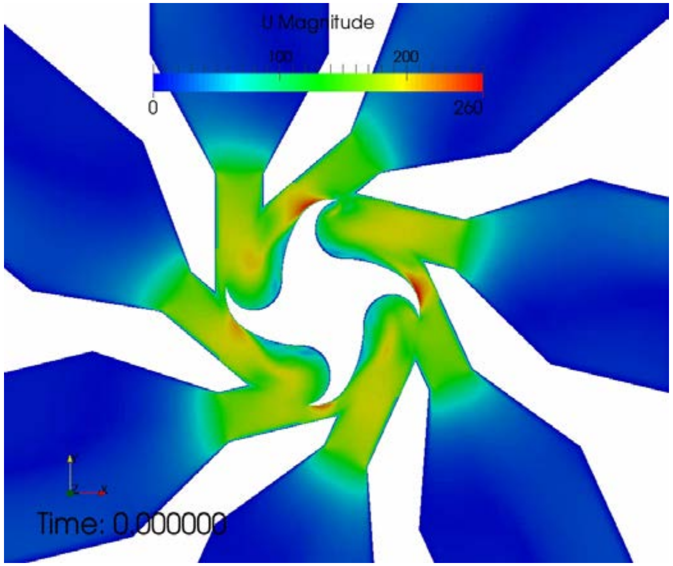

N. Herzog et al. «*Aerodynamic optimization of a micro-turbine inserted in an MAS system*»
accepted for publication in ASME Journal of Fluids Engineering