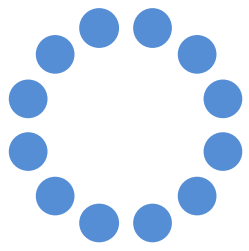


COMBUSTION BAY ONE

advanced combustion management

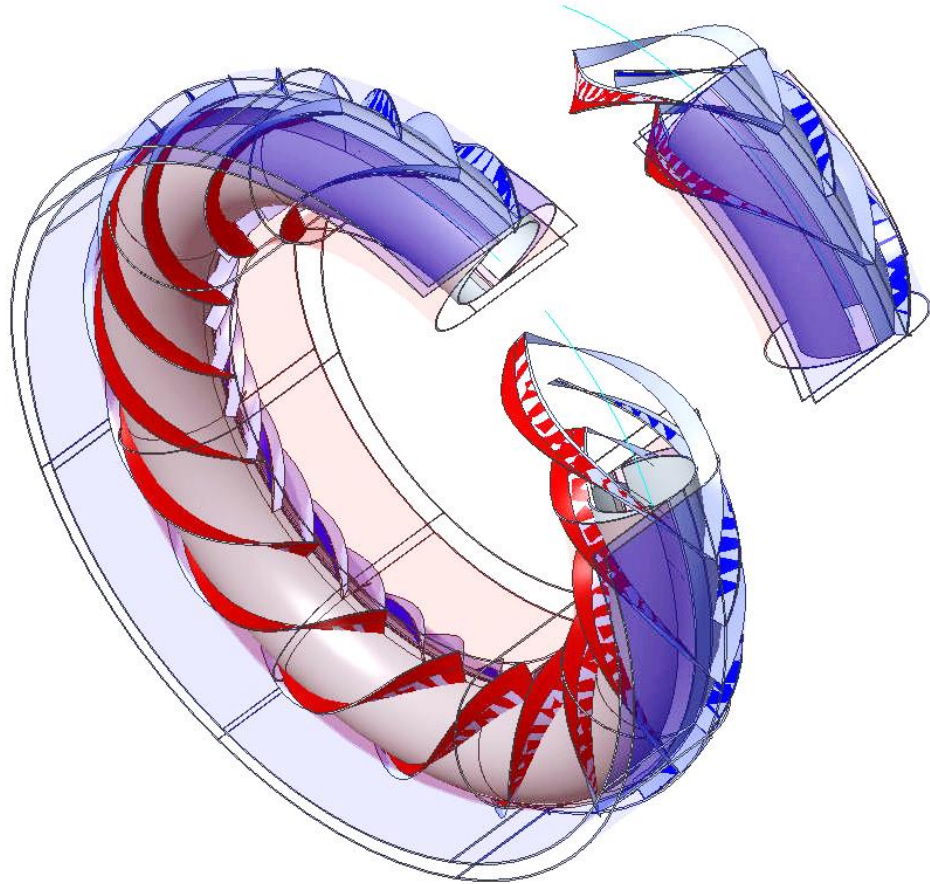


COMBUSTION BAY ONE

advanced combustion management

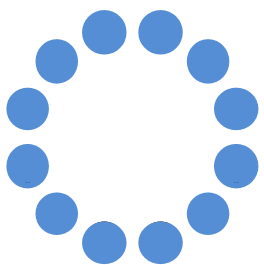
Recursive Sequential Combustion:

**An innovative and high-performance
combustion technology,
aimed at the fuels of the future**



Fabrice GIULIANI,
Nina PAULITSCH
Andrea HOFER
Bugra AKIN

Combustion Bay One e.U.,
Graz, Austria
www.CBOne.at



Authors and background

MOeBIUS

Recursive sequential combustor
using a MOmentum-Enhanced Blend
of reactants with recirculated bUrnt gaseS

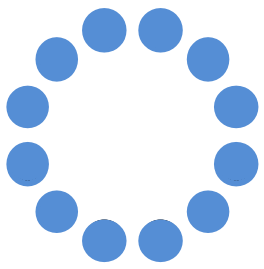
Project "MOeBIUS" / Take-Off programme / FFG, contract 881041

Project "RingOfFire" / Patent.Scheck / FFG, contract 876669

Project "rePeaT IP" / Patent.Scheck / FFG, contract 870672

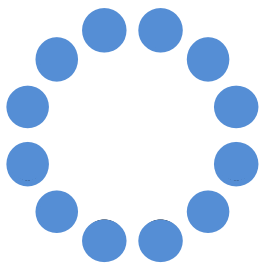


 Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

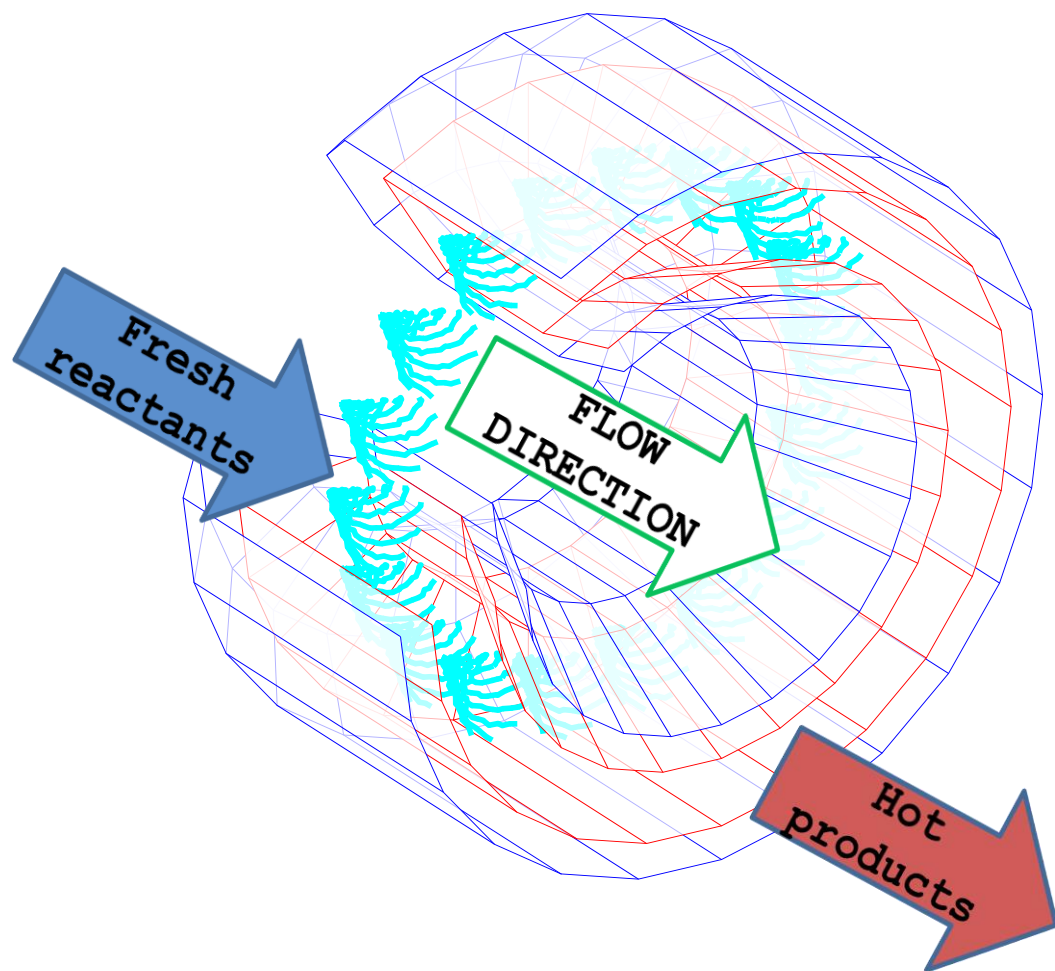


Contents

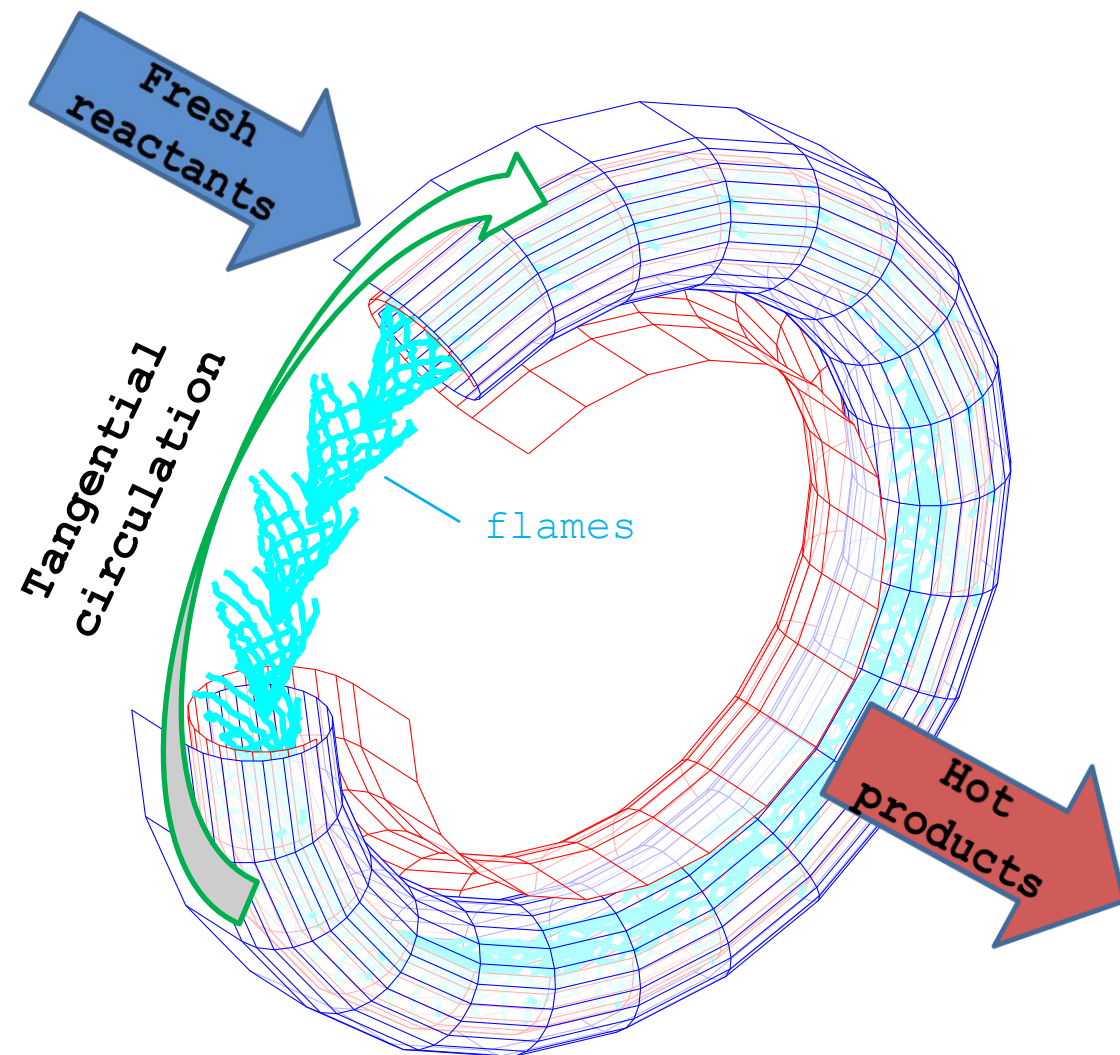
- MOeBIUS= Momentum-Enhanced Blend of the Reactants with Recirculated Burnt Gases
- Exploratory project, assessment and early implementation of the principle of sequential recursive combustion
- The principle
- The first results using reactive CFD
- Conclusion:
 - great expectations on this technology
 - a promising candidate for hydrogen burn

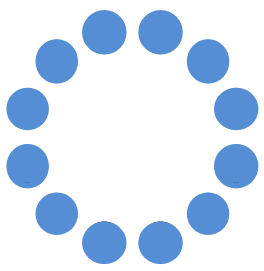


CONVENTIONAL



RECURSIVE SEQUENTIAL COMBUSTION





Recursive Sequential Combustion

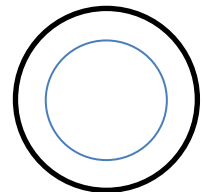
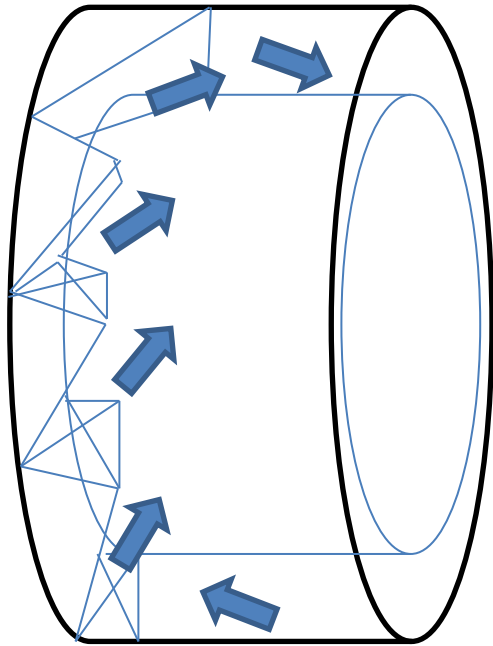
- A SAFE and ROBUST low-emission concept...
 - Low NO_x
 - Low soot
 - Highly heat conservative
- ... that combines
 - lean premixed combustion
 - Reburning (sequential combustion)



- The Recursive sequential Combustion
 - Maximises the azimuthal flow component
 - Maximises the interaction fresh reactants / Burnt gases
 - Stabilises the flame aerodynamically along the generatrix of the annular combustor
 - Is adequate for conventional / SAF fuels
 - Is promising regarding Hydrogen
- Keywords
 - **High-momentum flux injection**
 - **Fluidic-driven thermal inertia**
 - **Flow design**
 - **Mathematics to shape**
 - **Additive manufacturing**

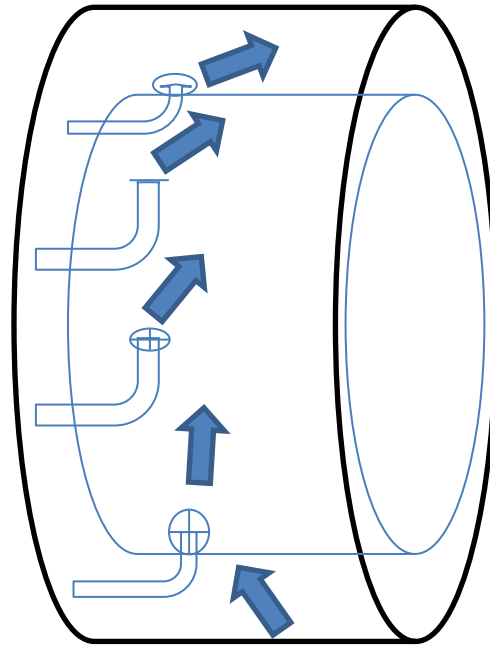
Exploitation of the azimuthal component

Short Helix Combustor,
Ariatabar et al., 2016

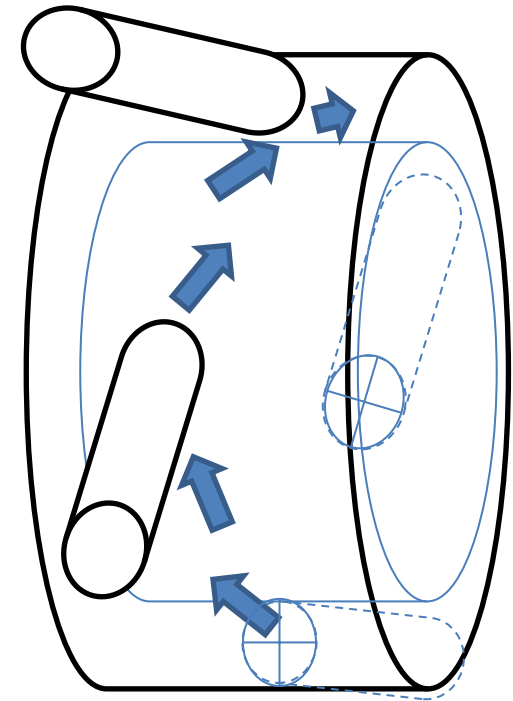


Annular Combustor

Spinning Combustion
Technology, Savary et al., 2016

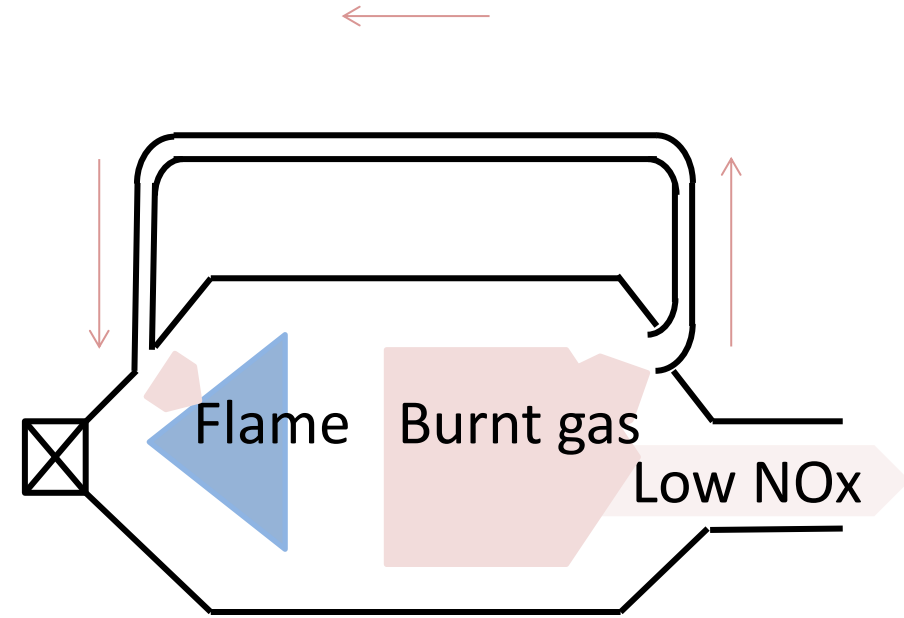


Tangential and Flameless Annular
Combustor, Toqan et al., 2015

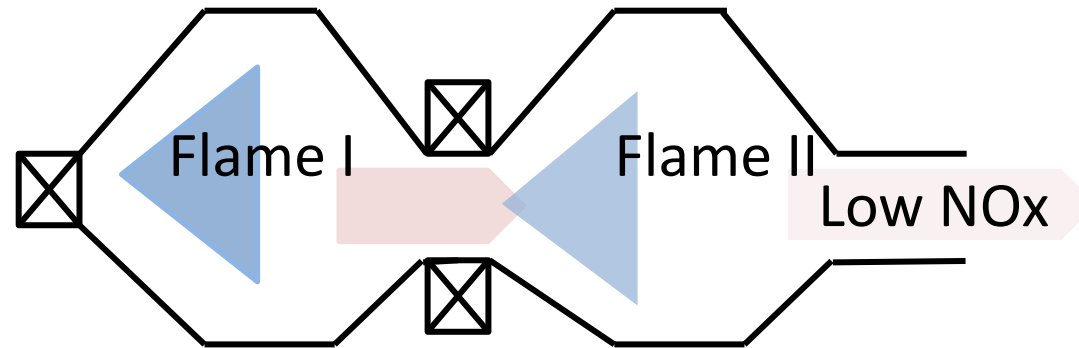


Burners or Injectors

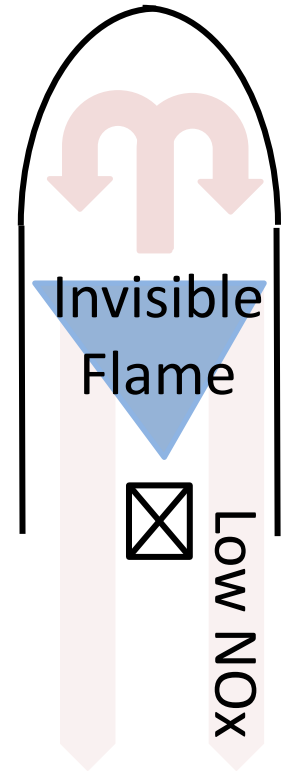
Exploitation of the burnt gases



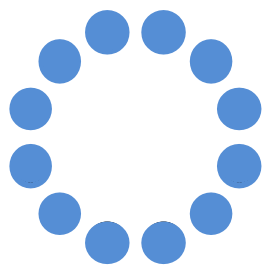
Flue gas recirculation,
Wilkes et al., 1980



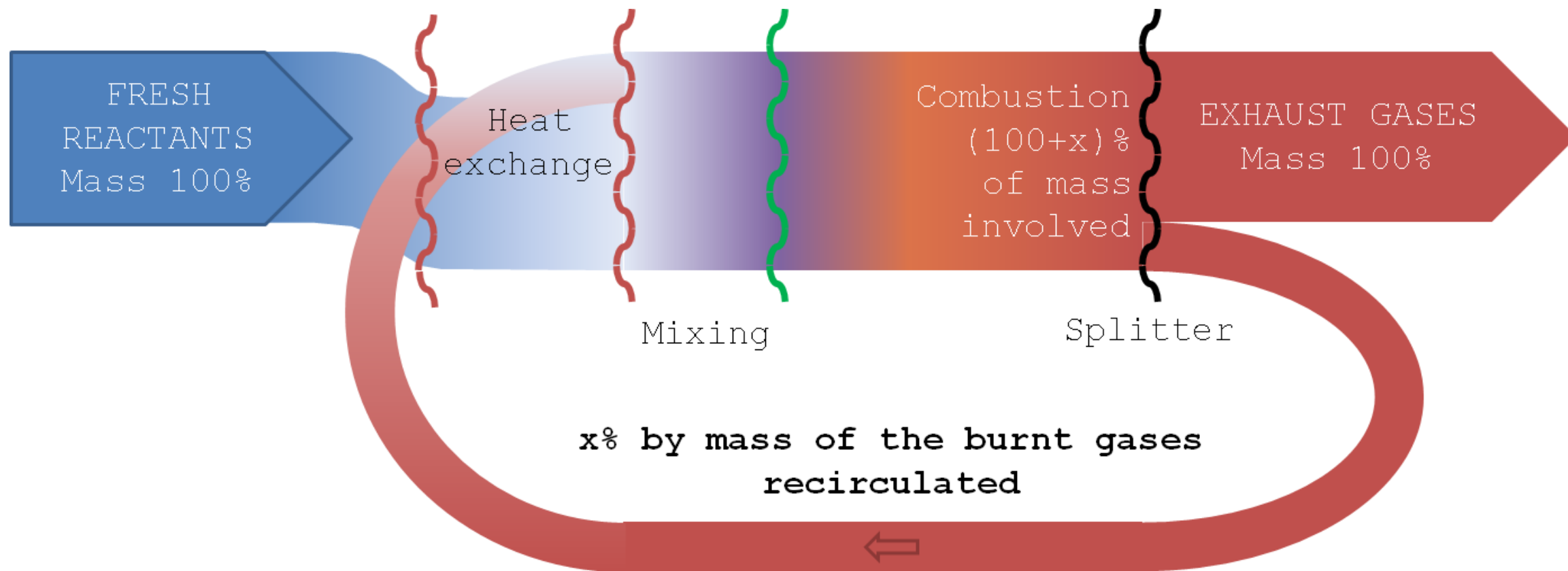
Sequential combustion
Pennell et al., 2017

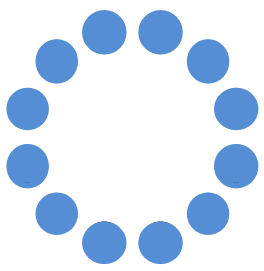


Flameless combustion,
Kruse et al, 2015

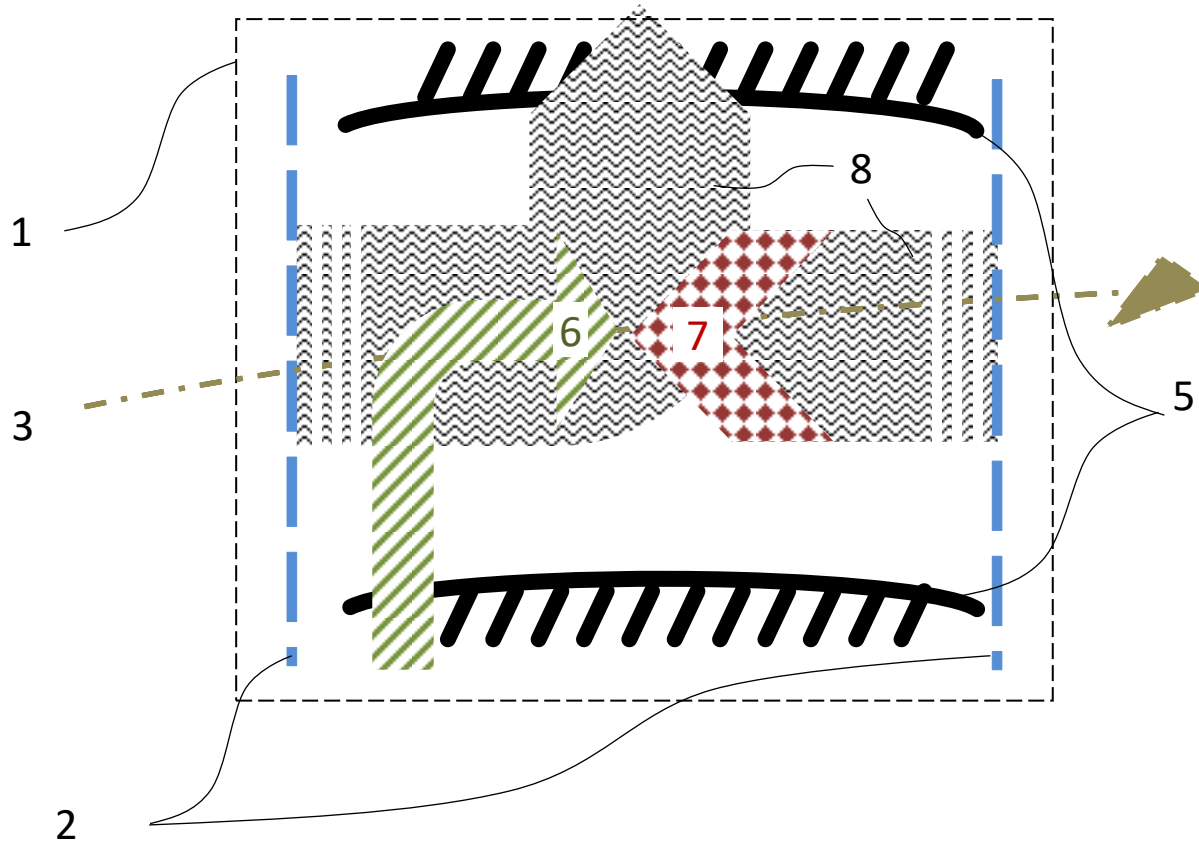


RSC at system level

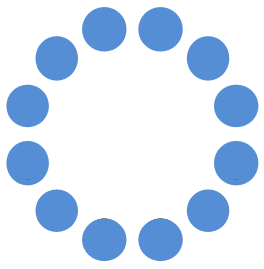




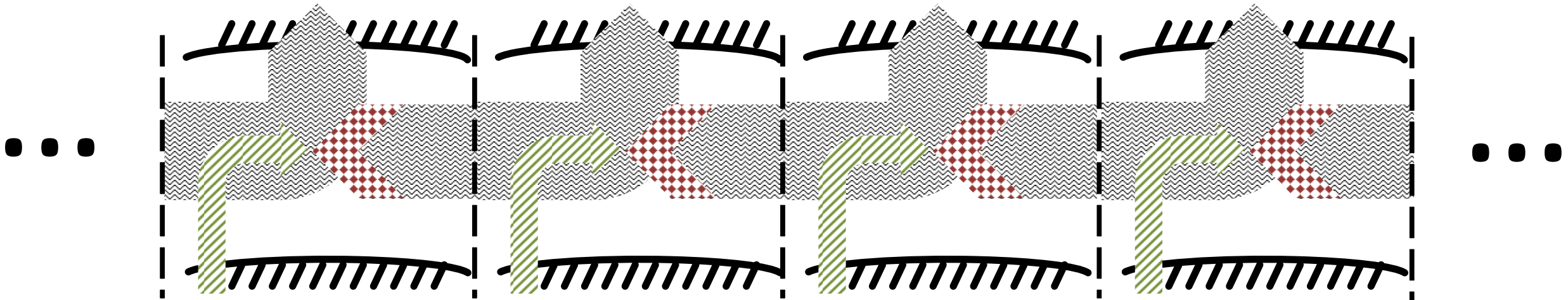
RSC at component level



- 1 The sector
- 2 Transition from one sector to the next
- 3 Azimuthal flow component along the generatrix
- 5 Walls
- 6 Fresh reactants
- 7 Flame
- 8 Burnt gases

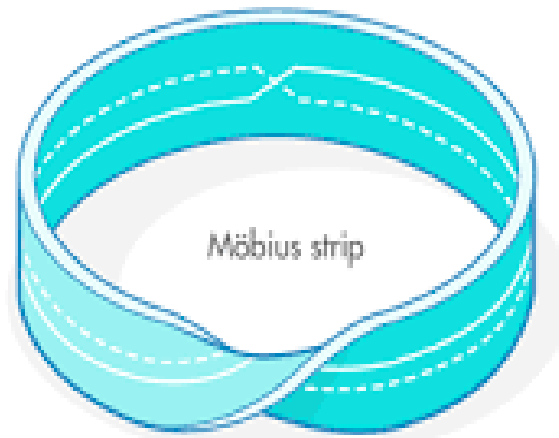


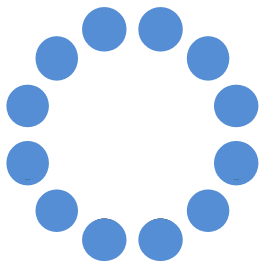
Recursive Sequential Combustion



MOeBIUS

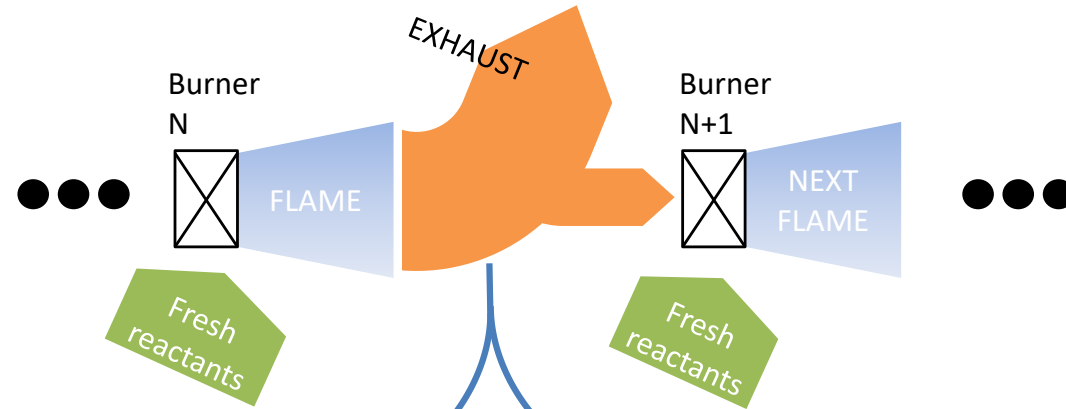
Recursive sequential combustor
using a MOmentum-Enhanced Blend
of reactants with recirculated bUrnt gaseS



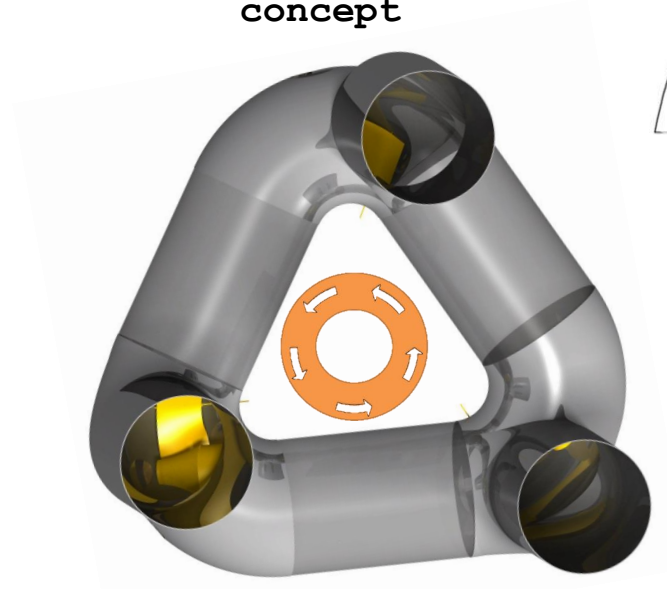


RSC concepts

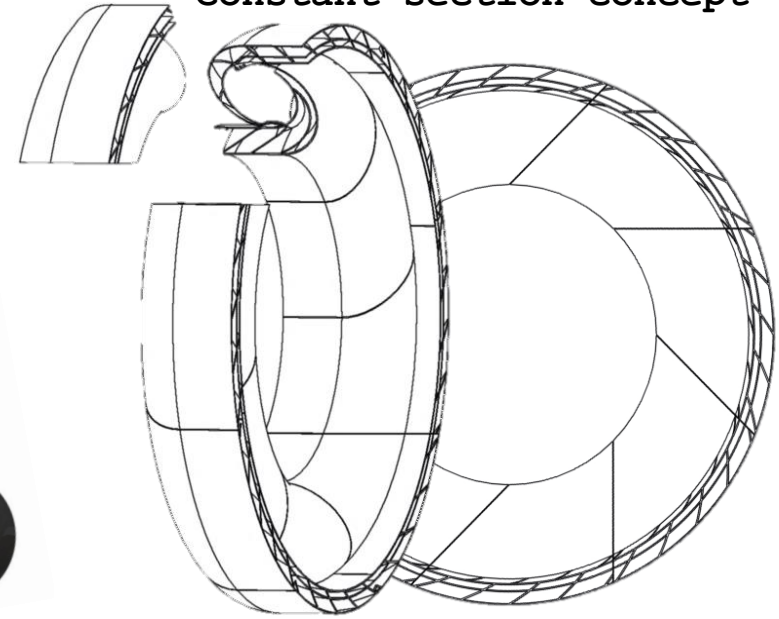
Recursive Sequential Combustion

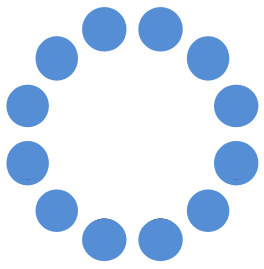


Discrete sector
concept

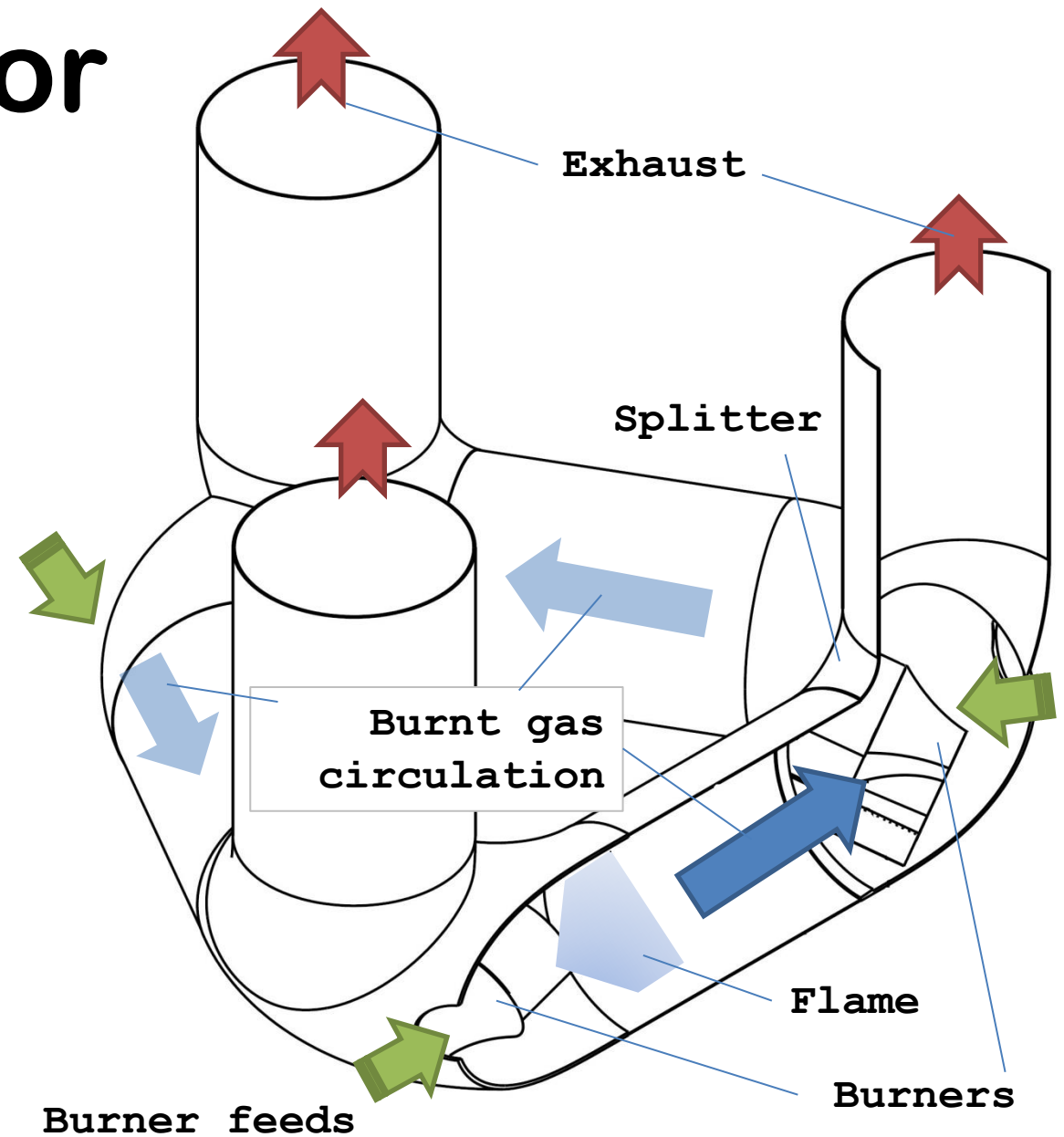
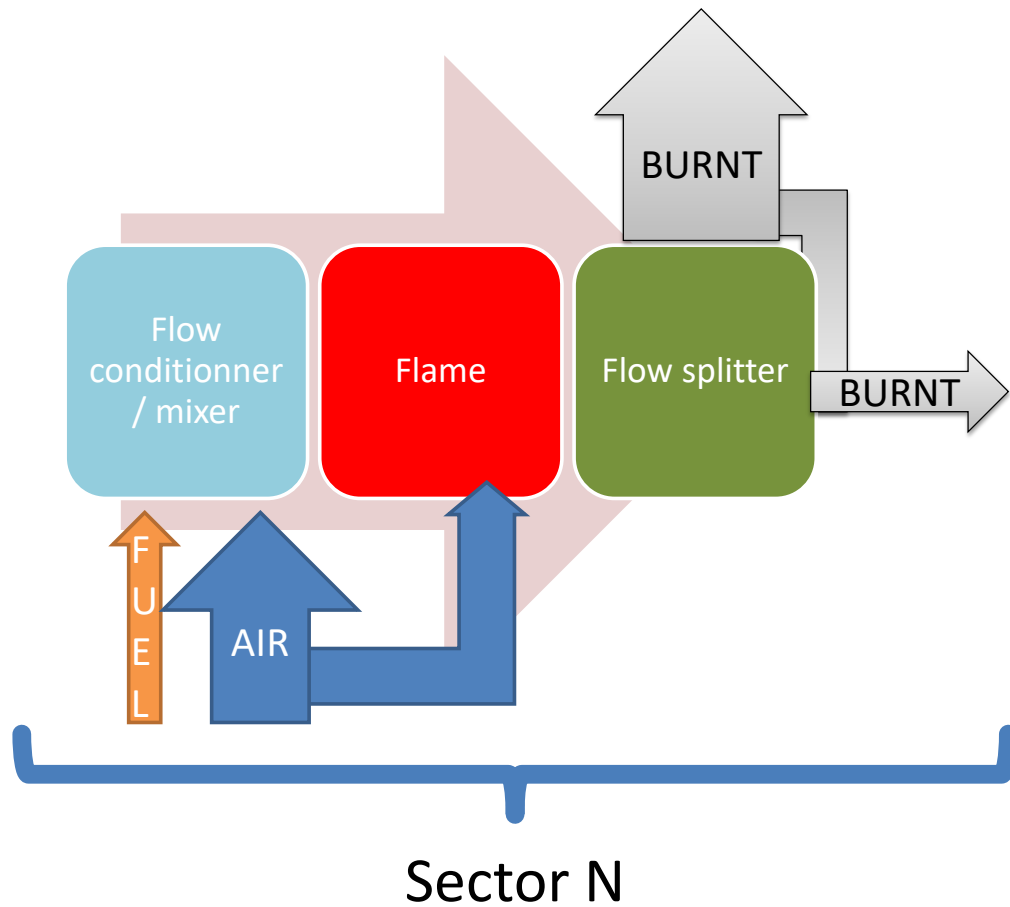


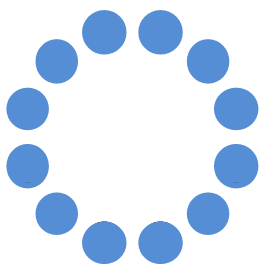
Constant section concept





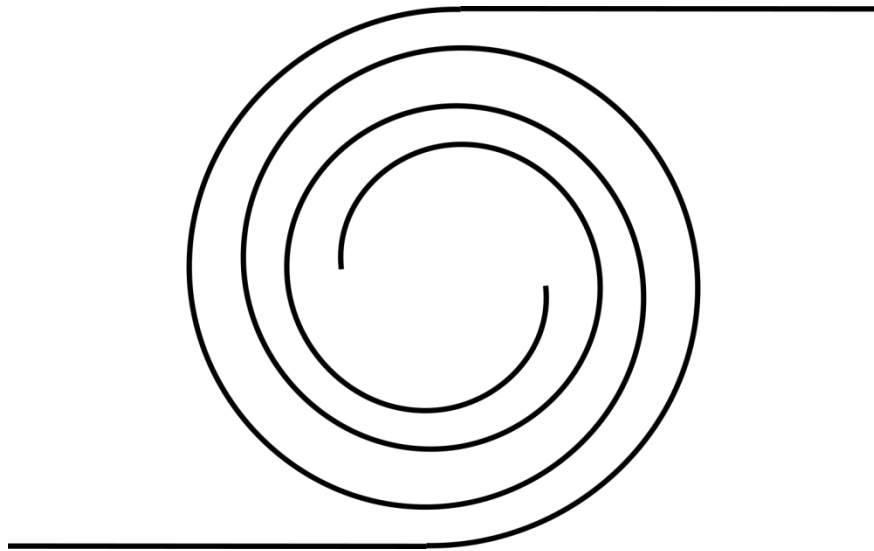
Discrete sector RSC concept



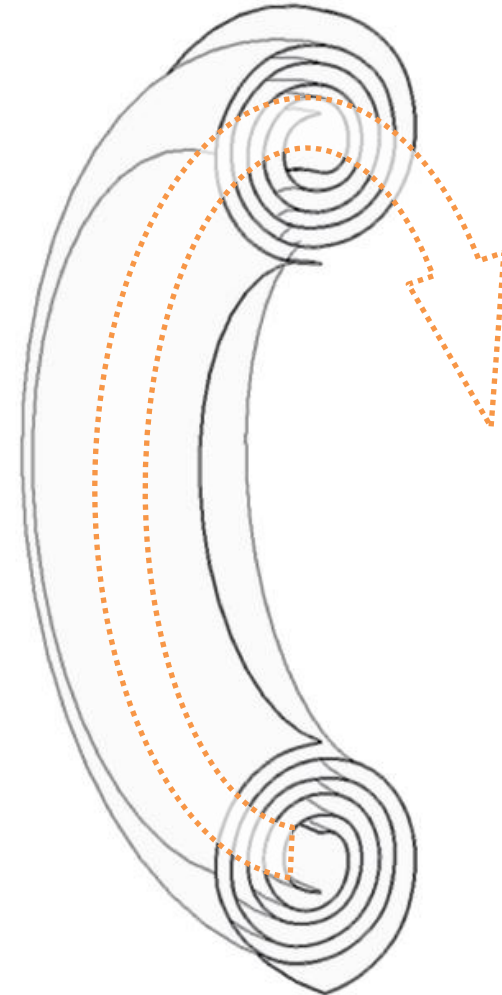


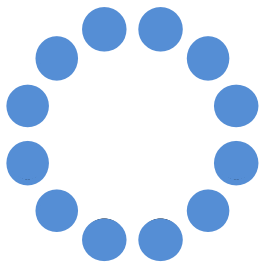
Constant section RSC concept

- Introducing the Swiss-Roll combustor (Weinberg, 1971; Shi et al, 2009)

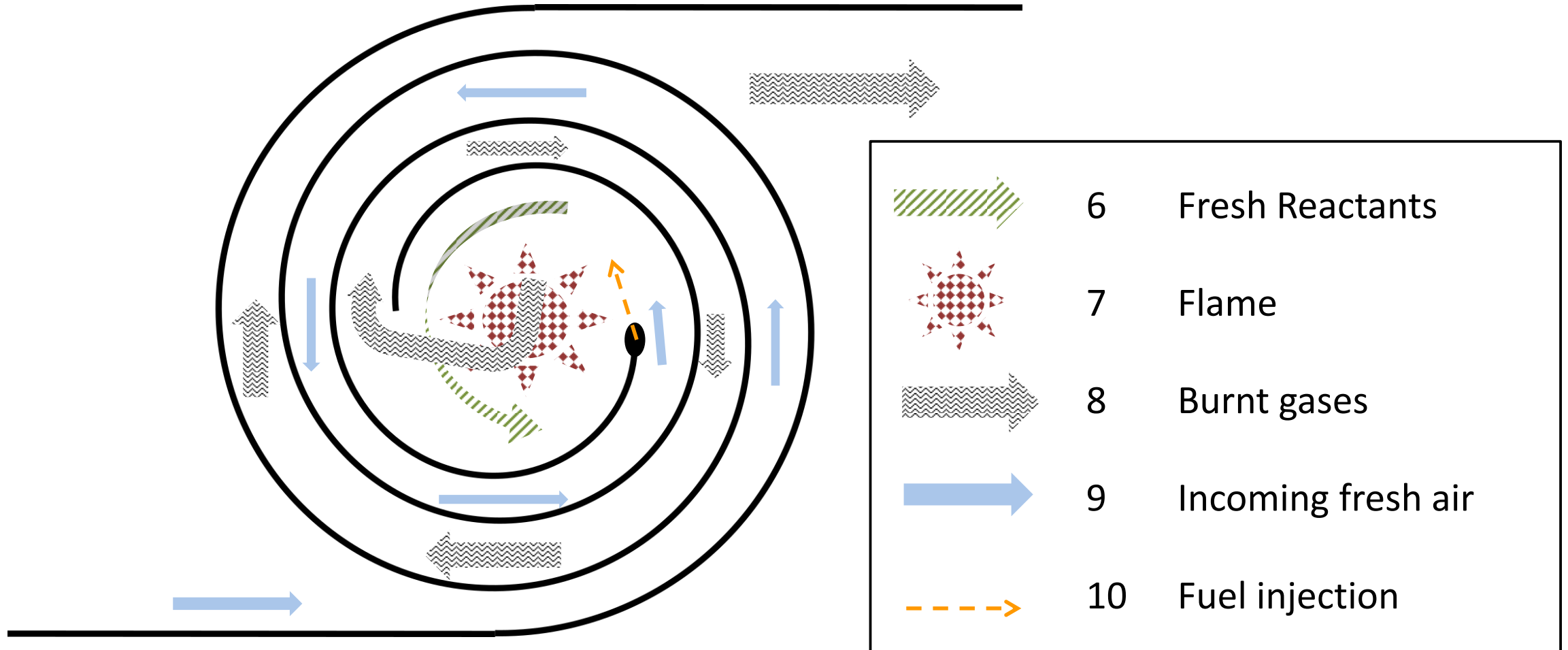


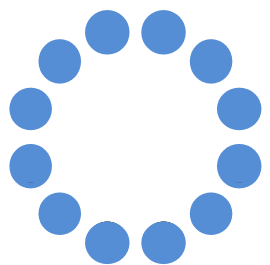
- Extruding it along a circular generatrix
- And inducing an azimuthal flow



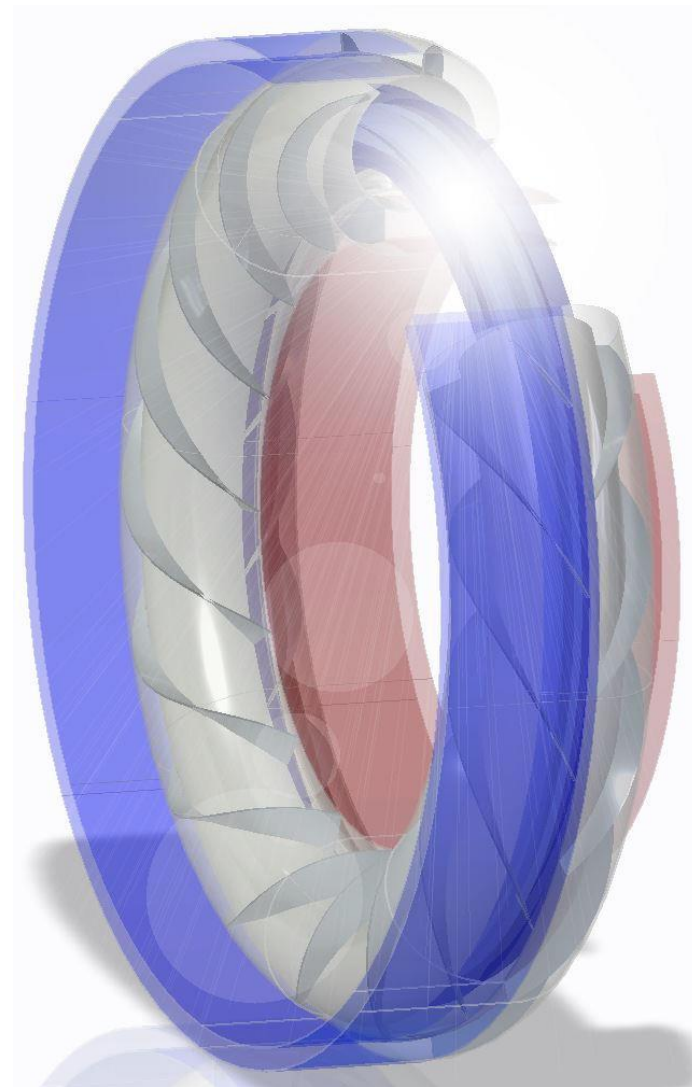
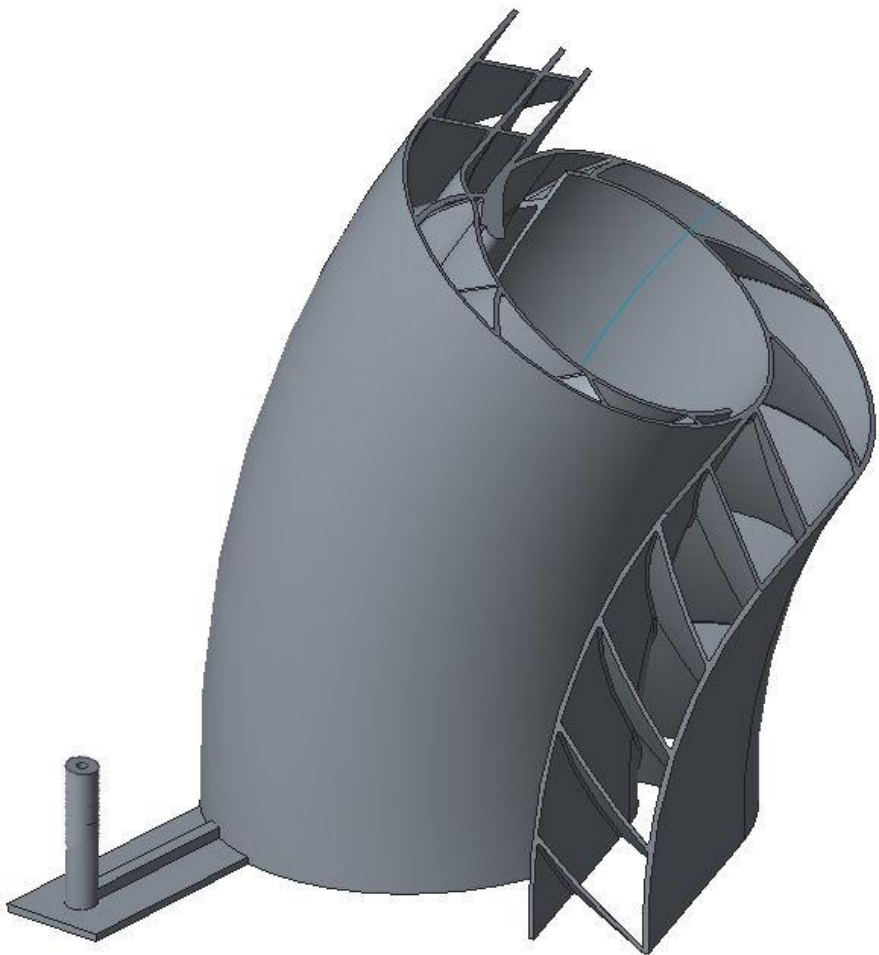


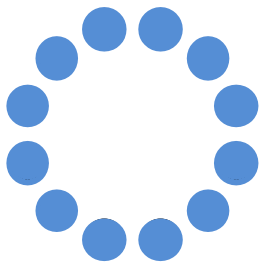
Constant section RSC concept



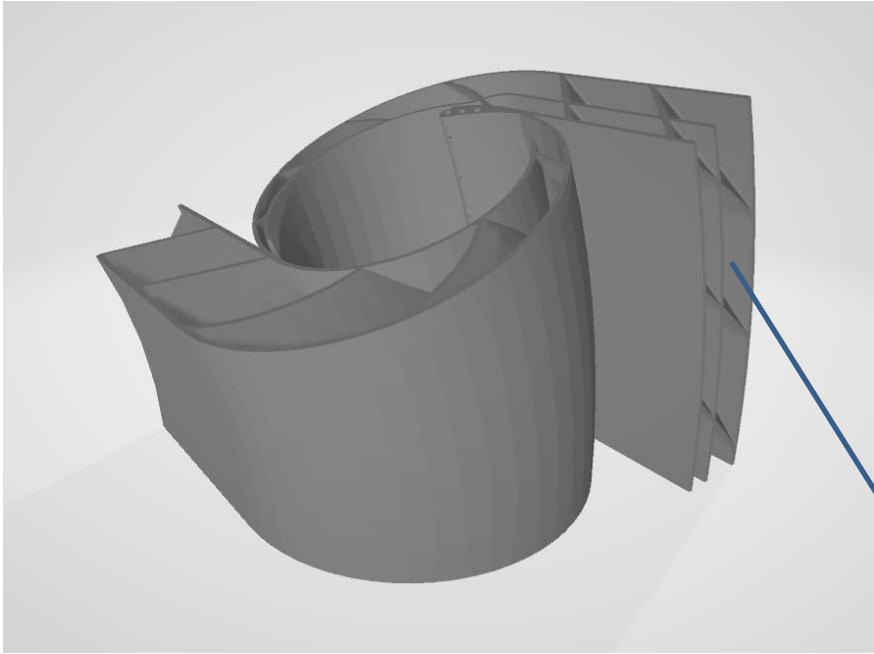


The MOeBIUS combustor

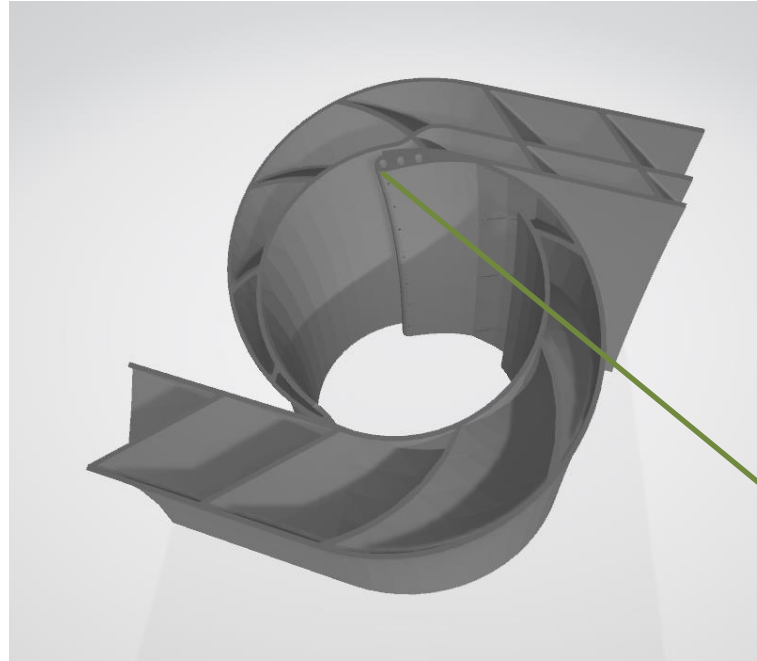




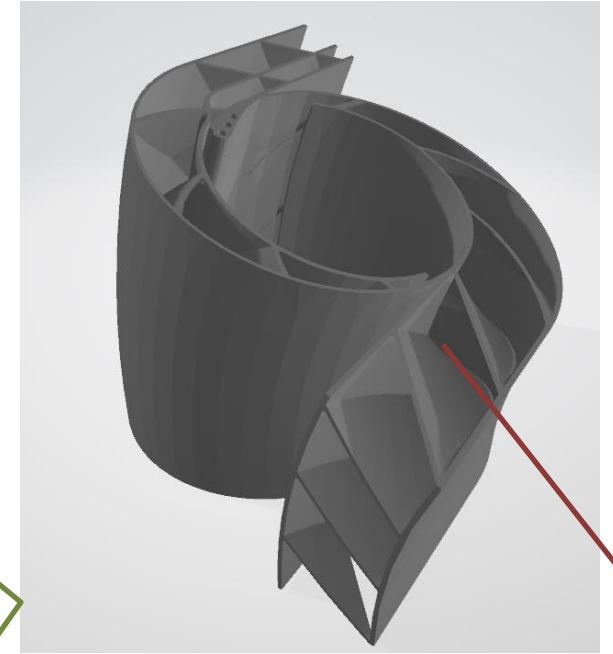
Functions of a sector



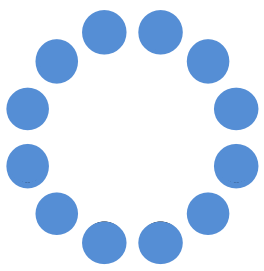
Inlet air coming from the compressor, subdivided into two channels



Fuel ramp (rePorT-type) for direct multipoint coke-free injection



Outlet with flow conditioning towards the turbine



Manufacturing options, focus on AM

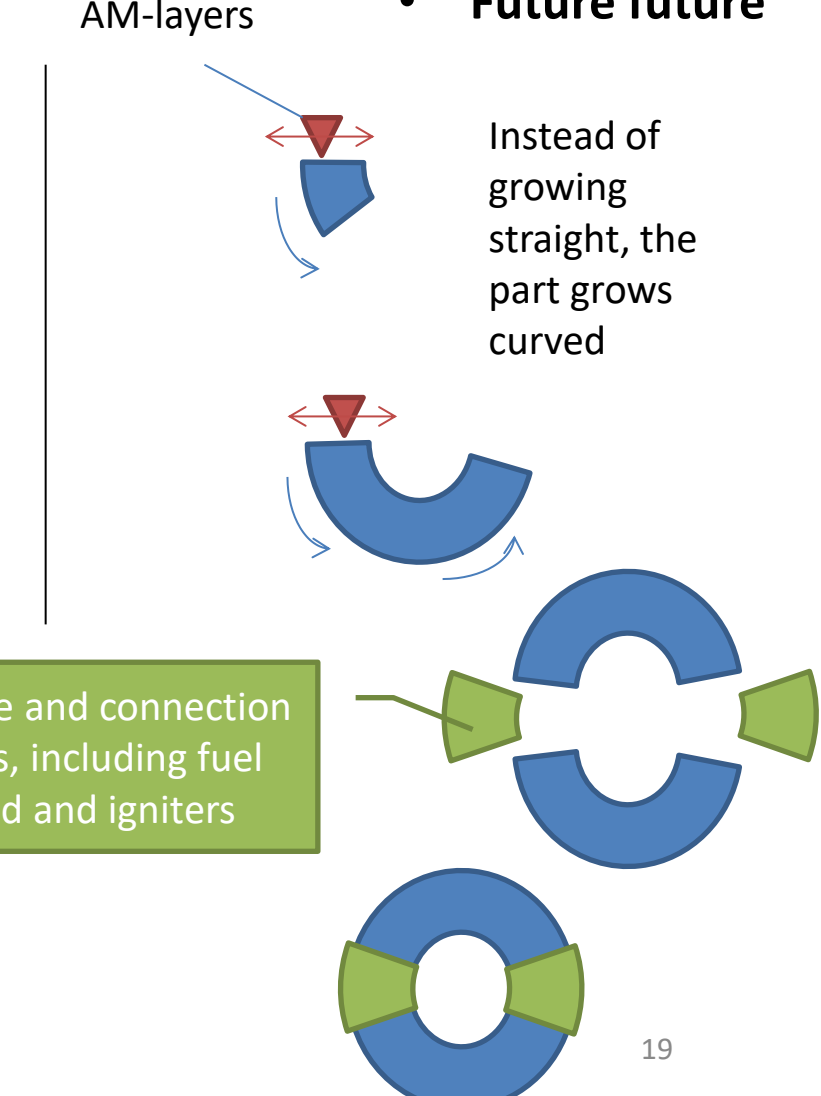
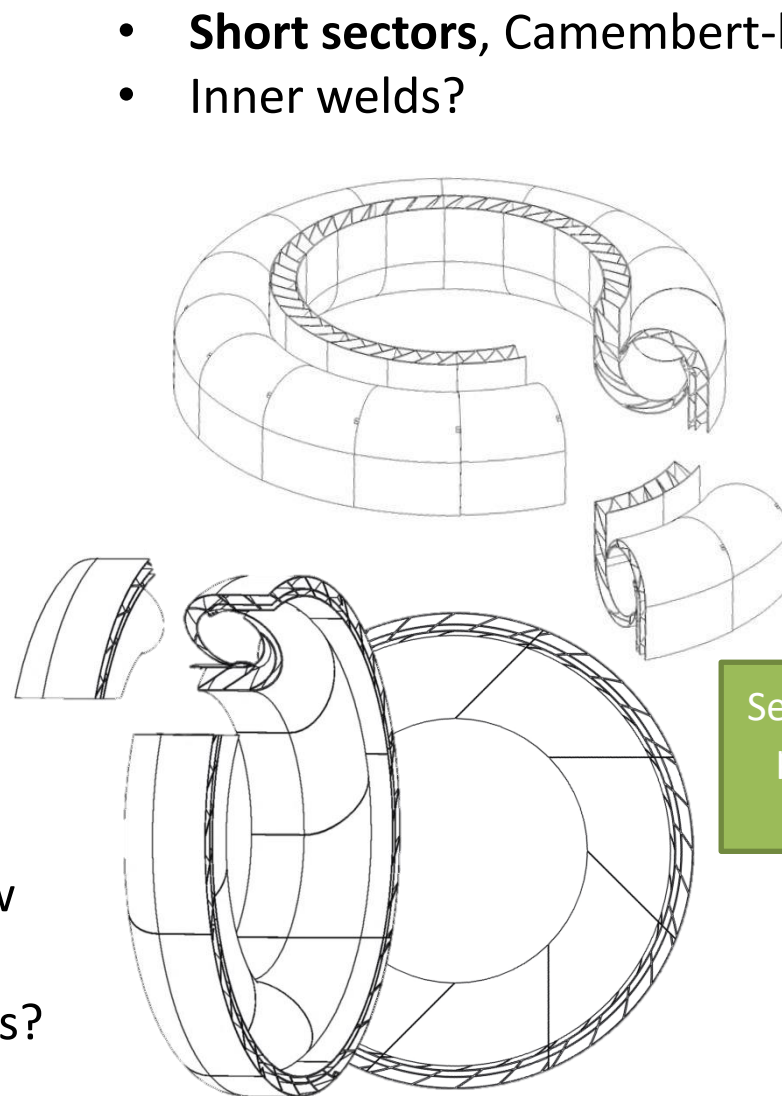
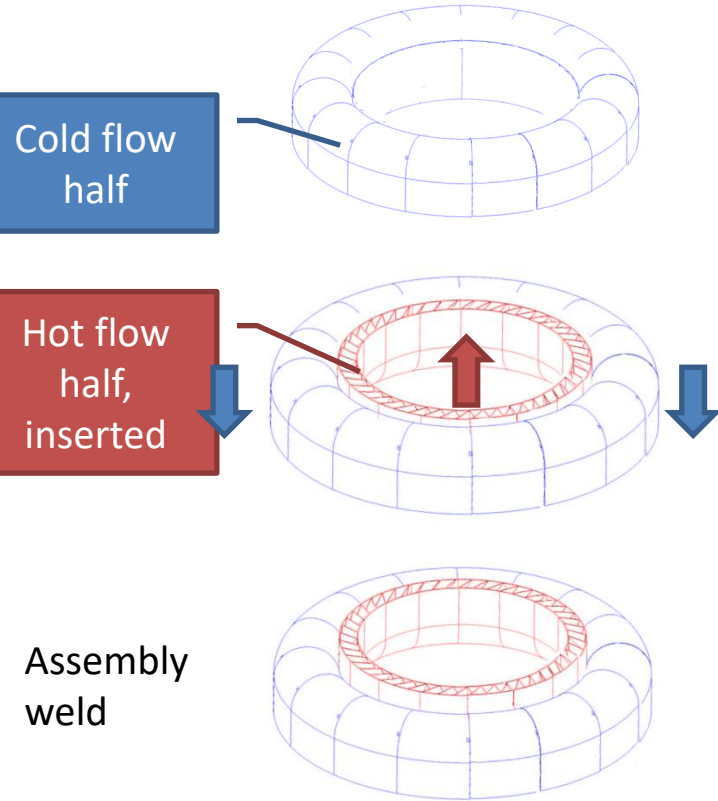
- **Short sectors, Camembert-like**
- Inner welds?

AM-layers

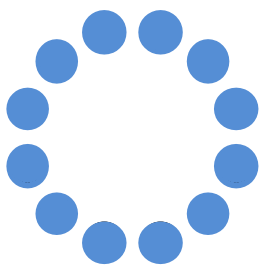
- **Future future**

Instead of growing straight, the part grows curved

Service and connection ports, including fuel feed and igniters

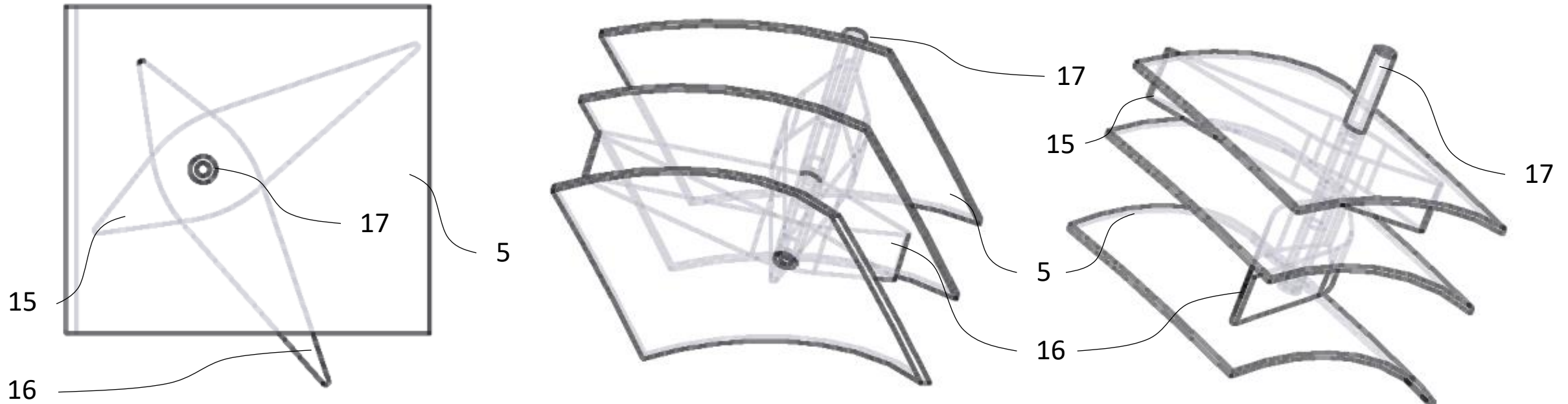


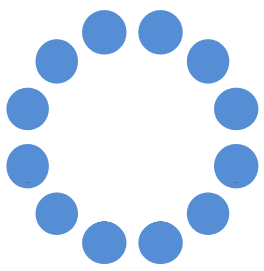
- **Conventional** as for return-flow combustors
- Sealing of the combustion torus?



Manufacturing details

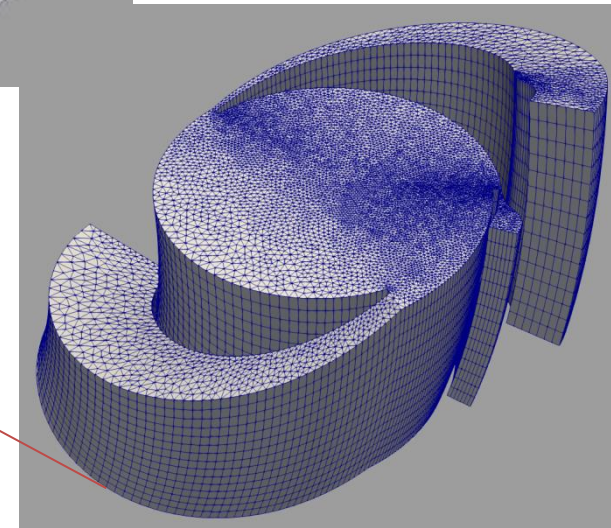
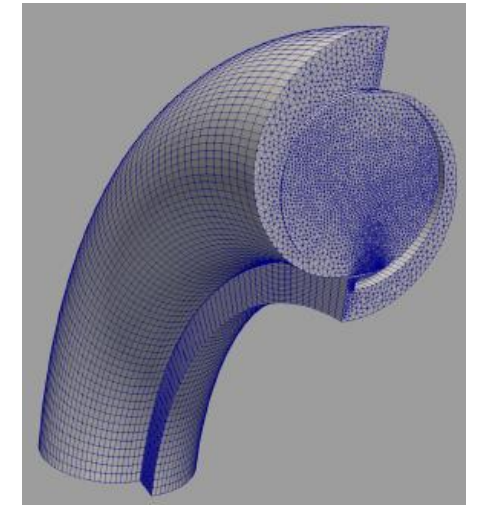
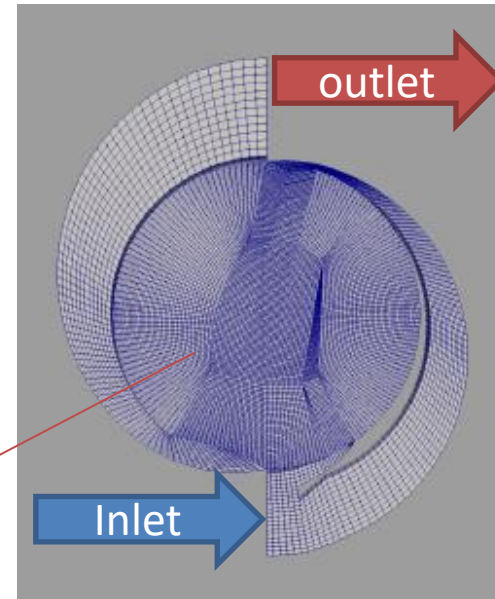
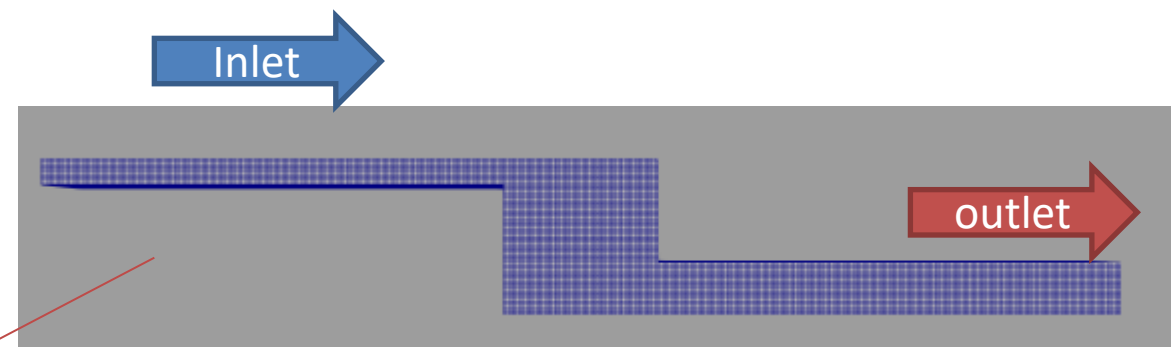
- Port connectors for fuel feed, instrumentation, igniter...

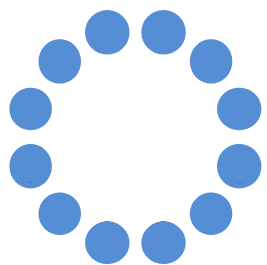




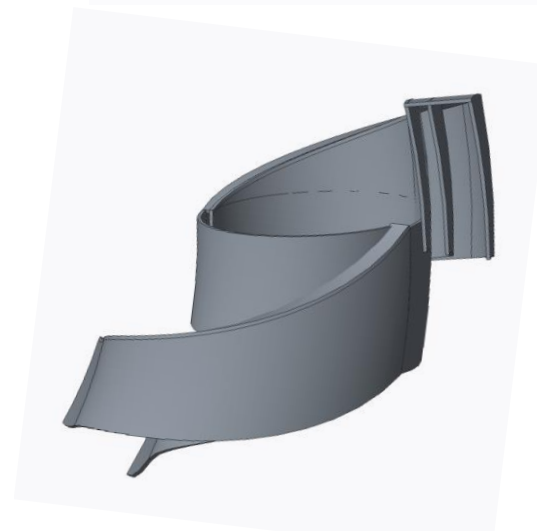
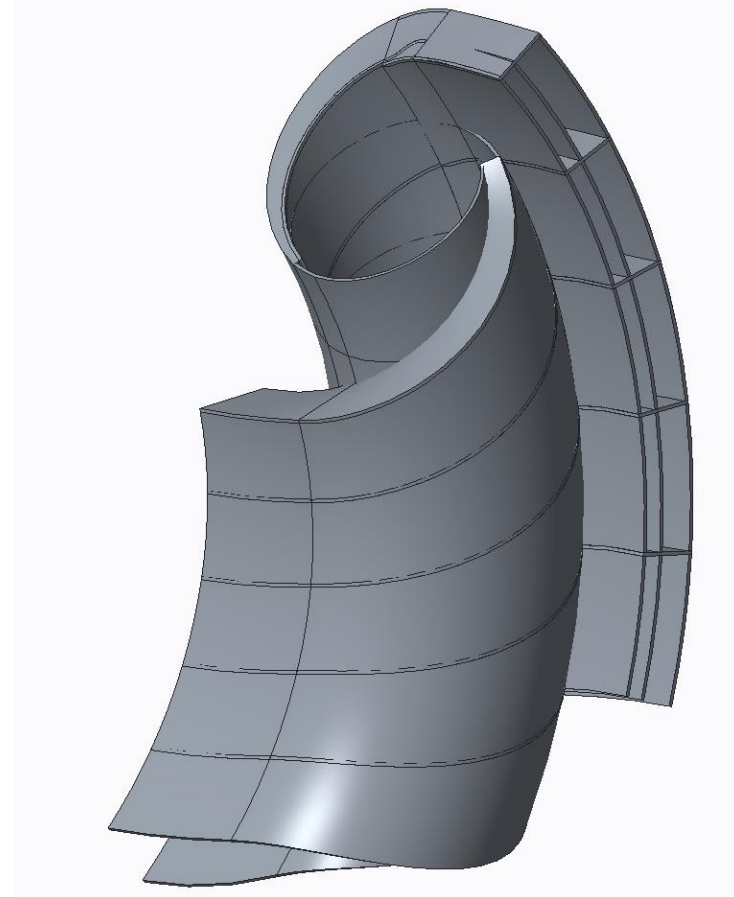
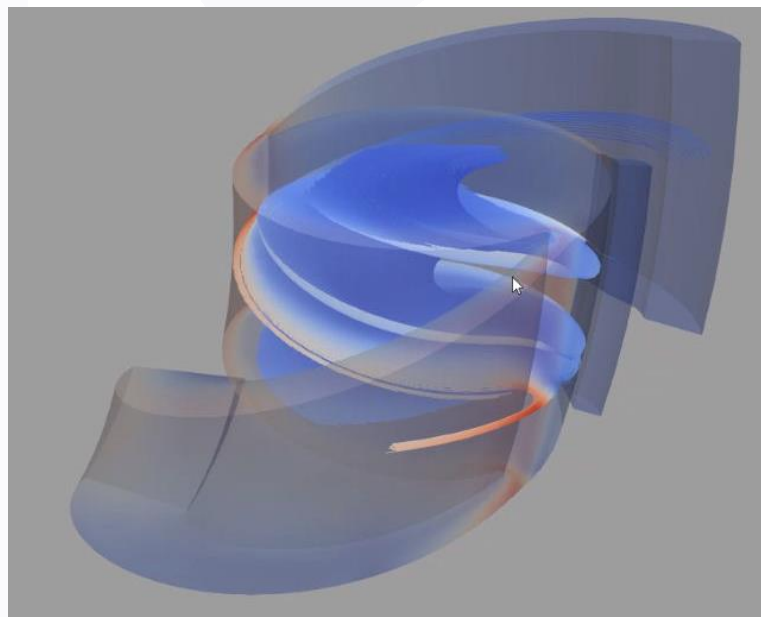
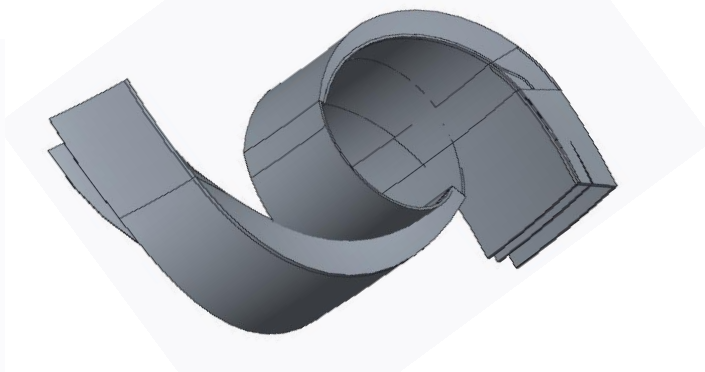
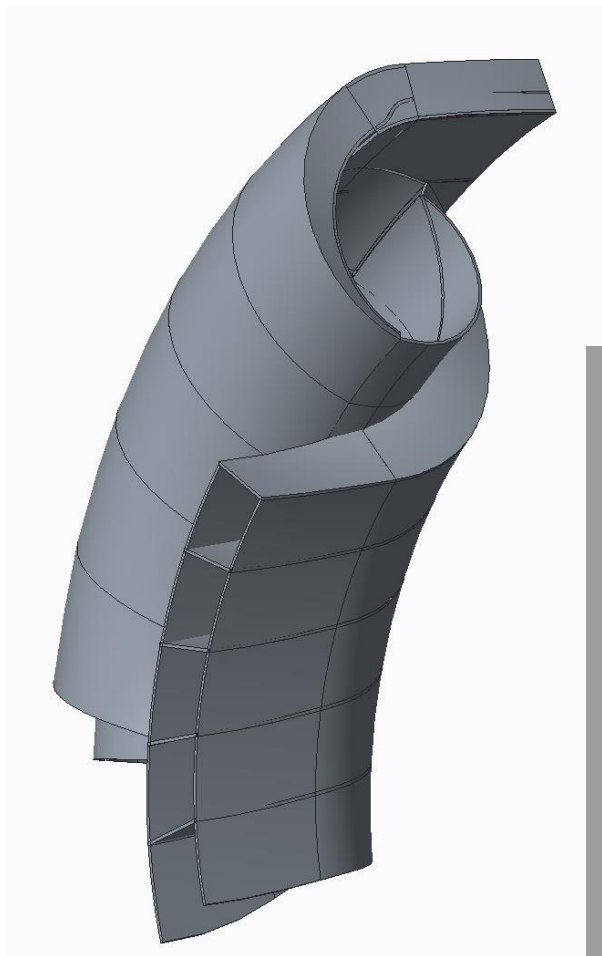
Modelling steps

- „Swiss Roll“ approach
- Same, profiled, curvilinear extruded
 - „Wedge“-> hypothesis on the circulation component
 - Full 3D model, with blades

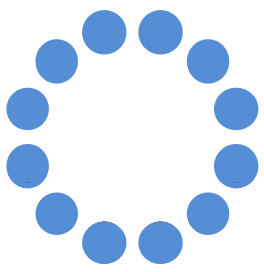




Modelling steps

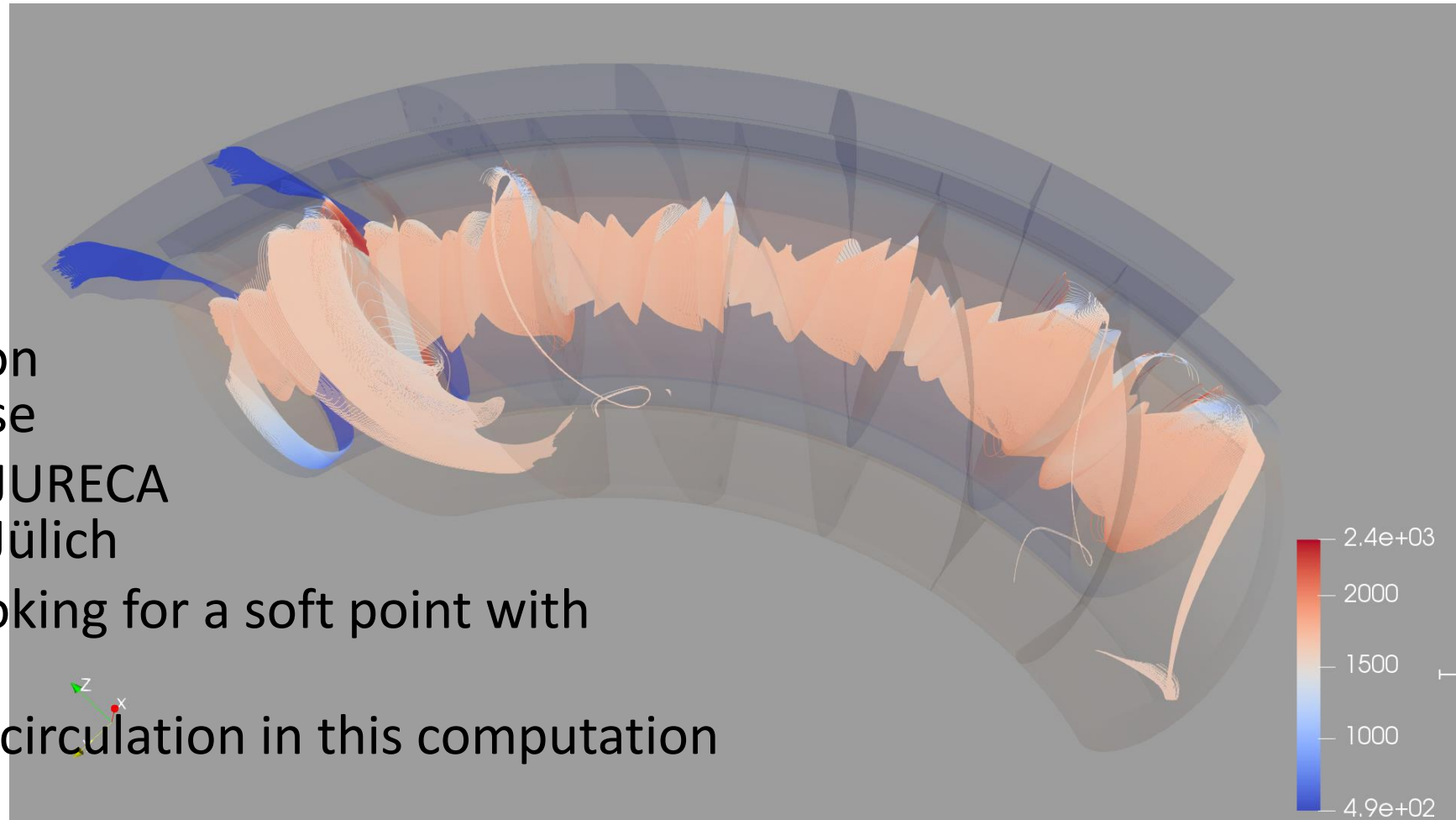


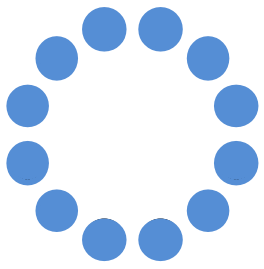
This particular design is also the one submitted to CFD



FULL 3D reactive CFD (constant section sector with blades)

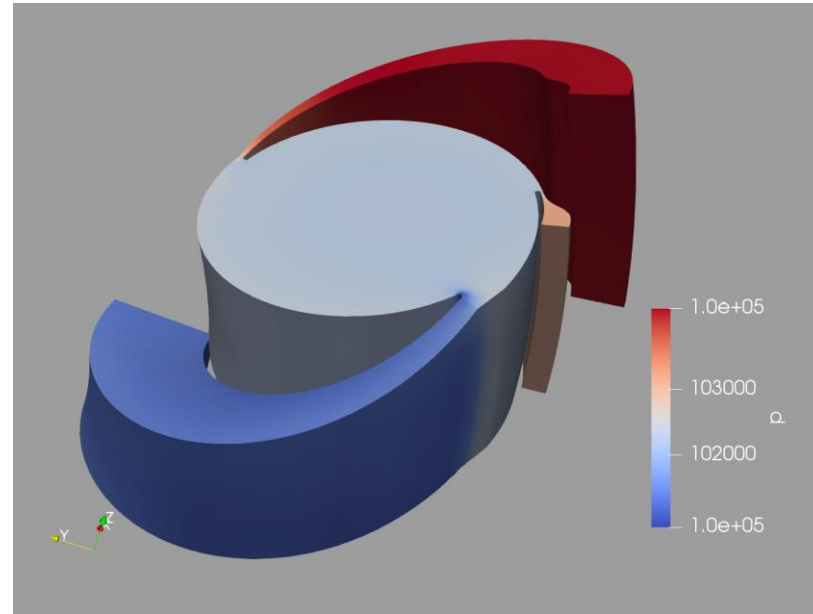
- Solver openFoam, selected after a benchmarking with Converge, based on the study of a swirl number on a reference test case
- Demanding CFD-> JURECA Supercomputer in Jülich
- This simulation: looking for a soft point with $T_{tet} \sim 1700-1800K$.
- 16% burnt gases recirculation in this computation



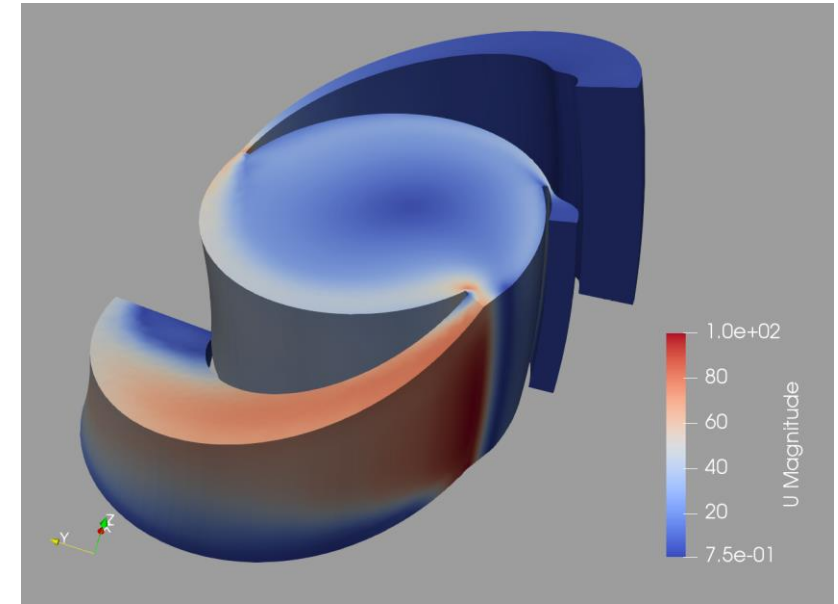


Full 3D reactive CFD

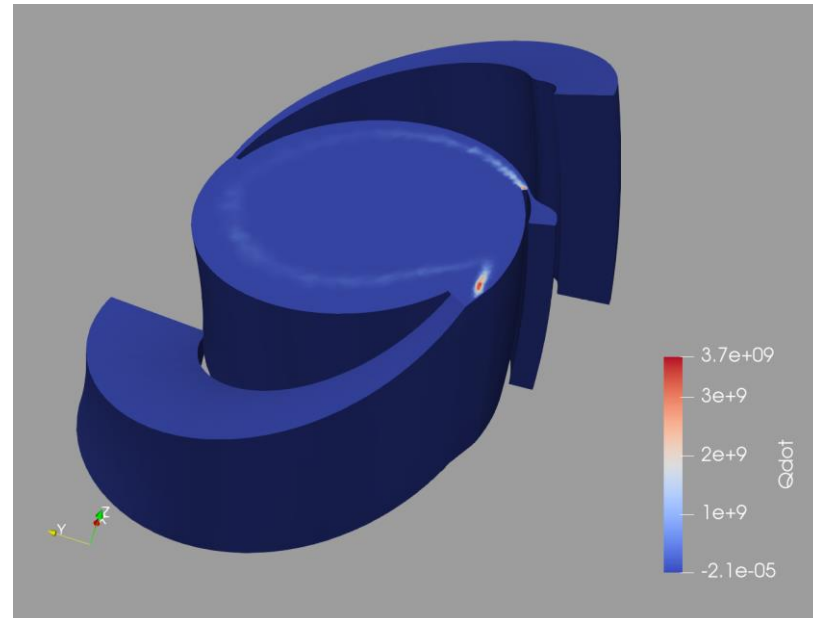
Total pressure [Pa]



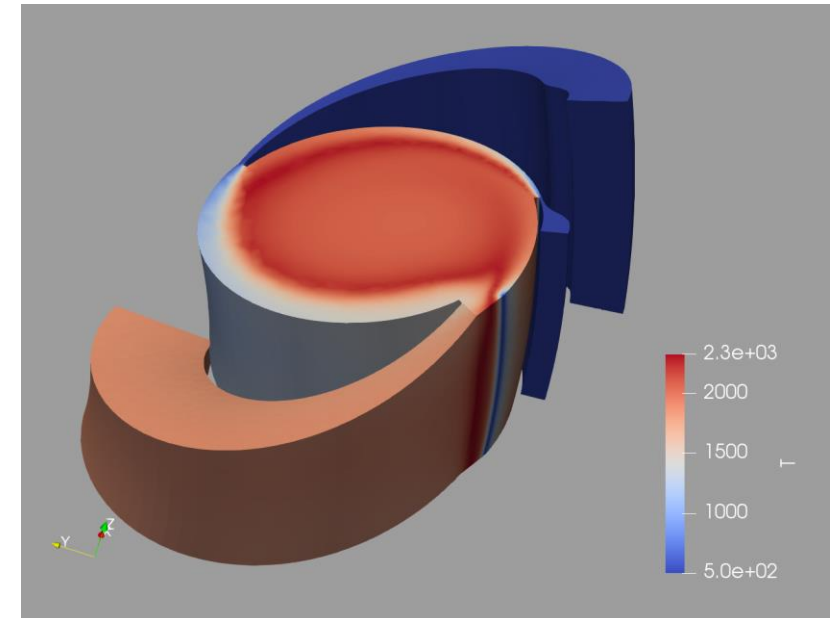
Absolute velocity [m/s]

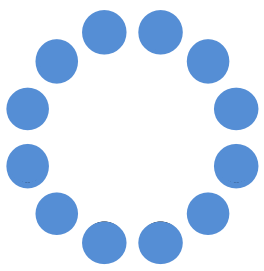


Heat release [kg/m/s³]



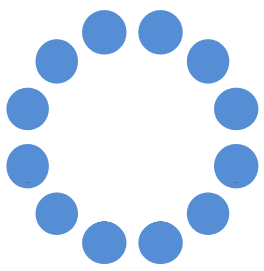
Temperature [K]





Conclusion

- Were introduced:
 - The Recursive Sequential Combustion
 - Two combustor concepts, the constant-section and the discrete burner configuration
- Effective progress was made:
 - ✓ Patent & publications
 - ✓ Diploma thesis
 - ✓ Concept plausibility established by simulations
 - ✓ Positive feedback from the industry
- Work in progress
 - Aerodynamics
 - Fuel placement
 - Refinement of the design sweet point (simulations)
 - Feasibility in terms of manufacturing (+integration)
 - Materials
 - Ignition process
 - Flame location
 - Combustion performance



Thank you for your attention!

See also

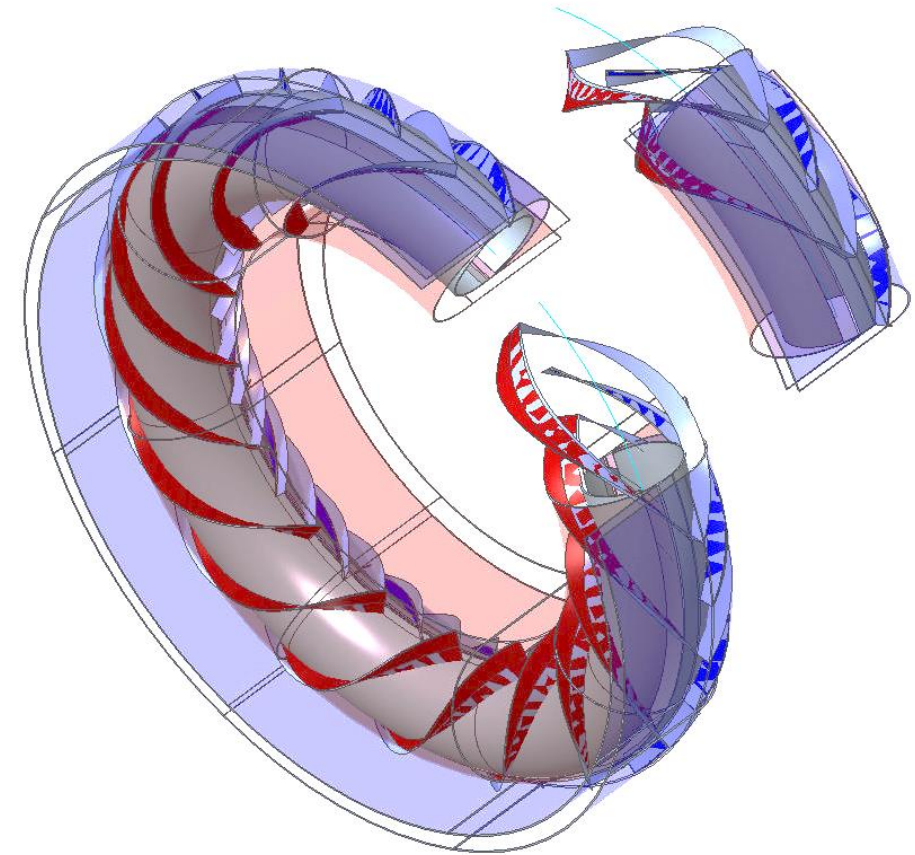
Recursive Sequential Combustion:
A Concept Study About a Momentum-Enhanced Blend
of the Reactants With Recirculated Burnt Gases

Fabrice Giuliani, Nina Paulitsch & Andrea Hofer

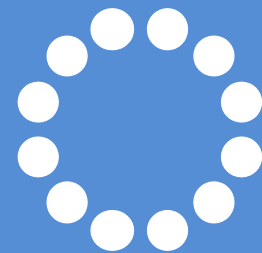
ASME Turbo Expo 2021, GT2021-59592

Combustion Bay One e.U.

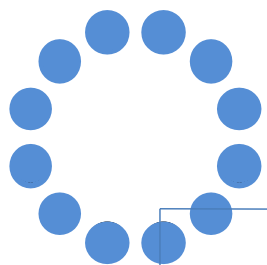
advanced combustion management
Schuetzenhofgasse 22,
8010 Graz, Austria



www.CBOne.at



COMBUSTION BAY ONE

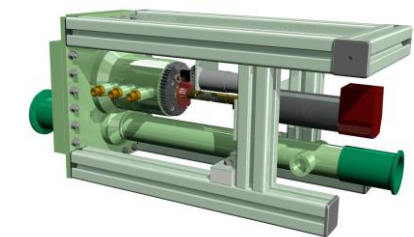
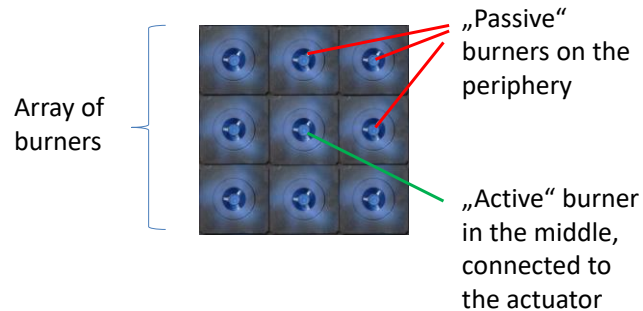


COMBUSTION BAY ONE

advanced combustion management



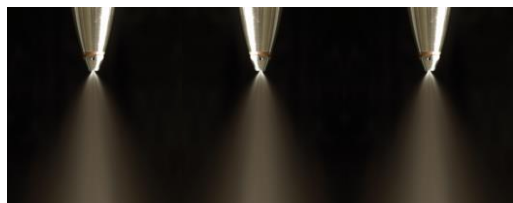
METHANULL



- Advanced control of the combustion turbulence
- Extension of the operation in the lean domain
- Improvement of the burner performance in off-design

Patent AT516424B1

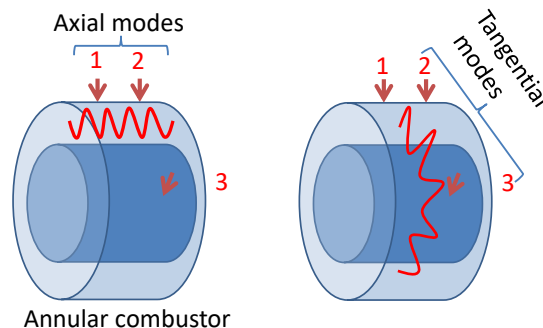
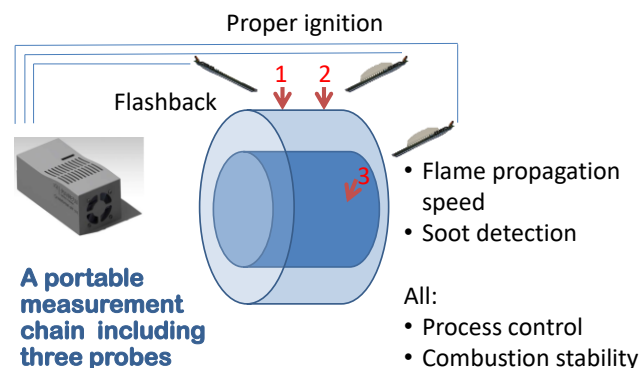
Four key enabling technologies



- Precision monitoring of the injection conditions of each separate injector
 - Embedded instrumentation using additive manufacturing
- Augmented process safety
- Real-time computation of the combustion output

Patent AT522614B1

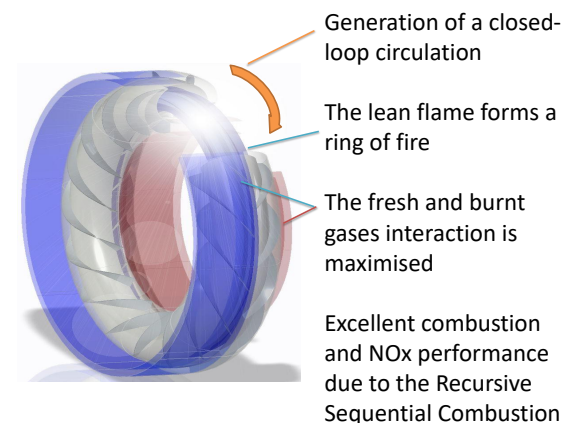
emootion



- In-Situ advanced combustion monitoring including optical techniques

Patent AT519720B1

MOeBIUS



- Augmentation of lean burn performance with recirculated burnt gases, and additional NOx reduction due to reburning
- Highly conservative heat core
- Disruptive technology, ready for hydrogen combustion

Patent AT523924B1
+ pending PCT patents