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Laboratory development of small DIAGONAL turbines for medium heads (25-100 m)

MHyLab – Aline Choulot

Hydro 2009 – session 17

27.10.09

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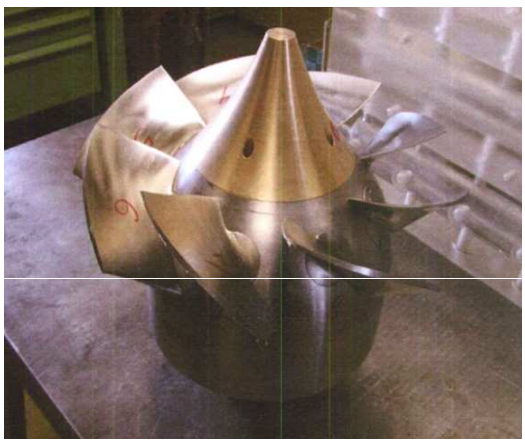
State of the art – a few units – in the large hydropower field

CKD Blansko

Andritz – Culligran – 17 MW – scale model



Deriaz turbines – pump turbines

Medium head sites usually equipped with Francis

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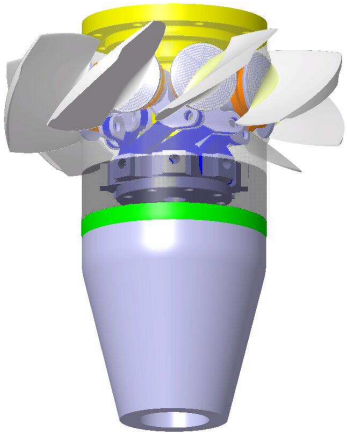
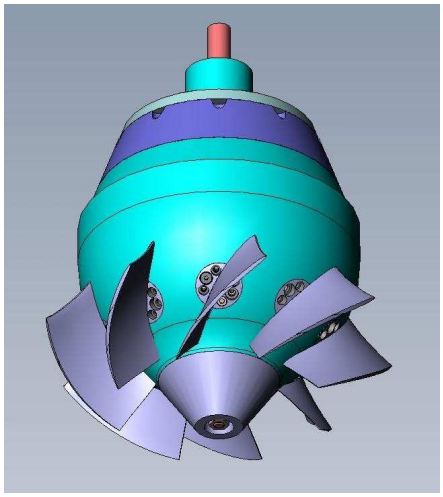
Diagonals: at the crossing between Axial and Francis turbines



Axial runner (Kaplan)
1 m - 30 m



Diagonal runner
25 m – 100 m

Francis runner
20 m – 100 m

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Euler equation

$$\eta_h \cdot gH = N \cdot (R_1 \cdot Cu_1 - R_2 \cdot Cu_2) \quad [J/kg]$$

- η_h = Energetic efficiency with which the transfer between the inlet and the outlet of the blade operates [-]
- gH = mass hydraulic energy available for the turbine [J/kg]
- N = angular rotation speed of the turbine [-/s]
- R_1 , R_2 = radius of the meeting point of a liquid stream at the inlet / outlet sledge of the blade [m]
- Cu_1 , Cu_2 = circumference component of the liquid stream speed at R_1 / R_2 radius [m/s]

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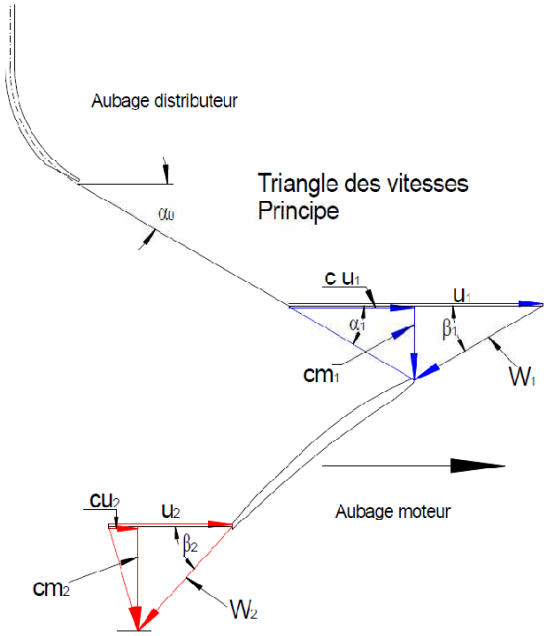
Euler equation

$gHh = N \cdot (R1 \cdot Cu1 - R2 \cdot Cu2)$ [J/kg]

To ⇒ H, 2 possibilities:

- To ⇒ $(Cu_1 - Cu_2)$ by ⇒ $(\beta_1 - \beta_2)$,

but cavitation



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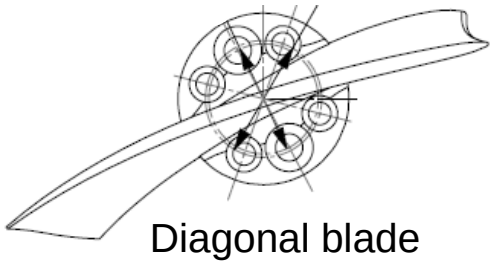
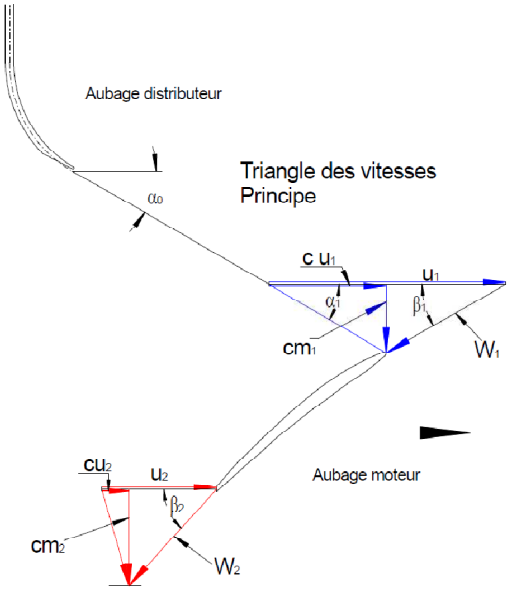
Axial / Diagonal blade profile speed triangle & cavitation

Axial blade – cavitation for H > 30 m



Diagonal blade

$gHh = N \cdot (R1 \cdot Cu1 - R2 \cdot Cu2)$ [J/kg]



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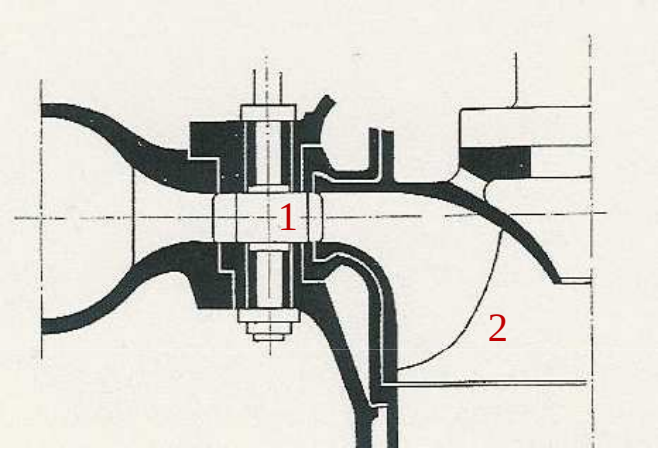
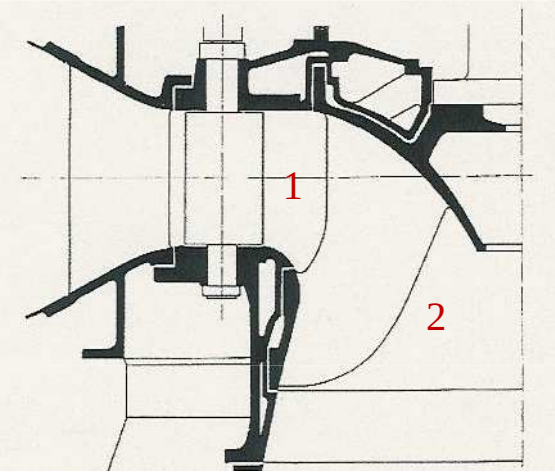
Euler and Francis - R_1 & R_2





H = 522 m

$R_1 >> R_2$

H = 56 m

$R_1 \cong R_2$

Source: feuille de cours illustrées, B, Th. Bovet, EPFL

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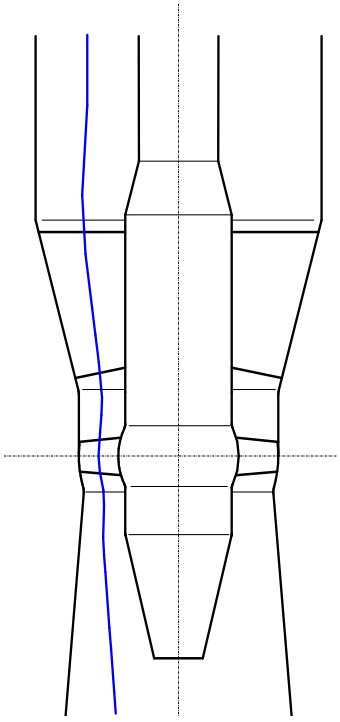
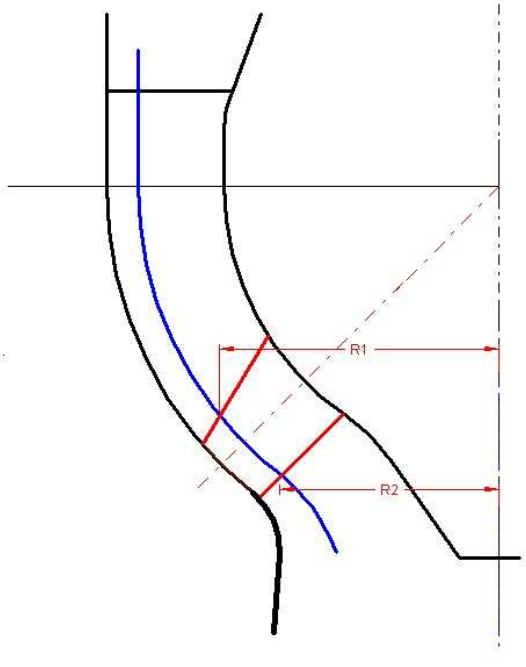
Euler : R1 & R2



Axial turbine: $R_1 \cong R_2$



Diagonal turbine: $R_1 > R_2$

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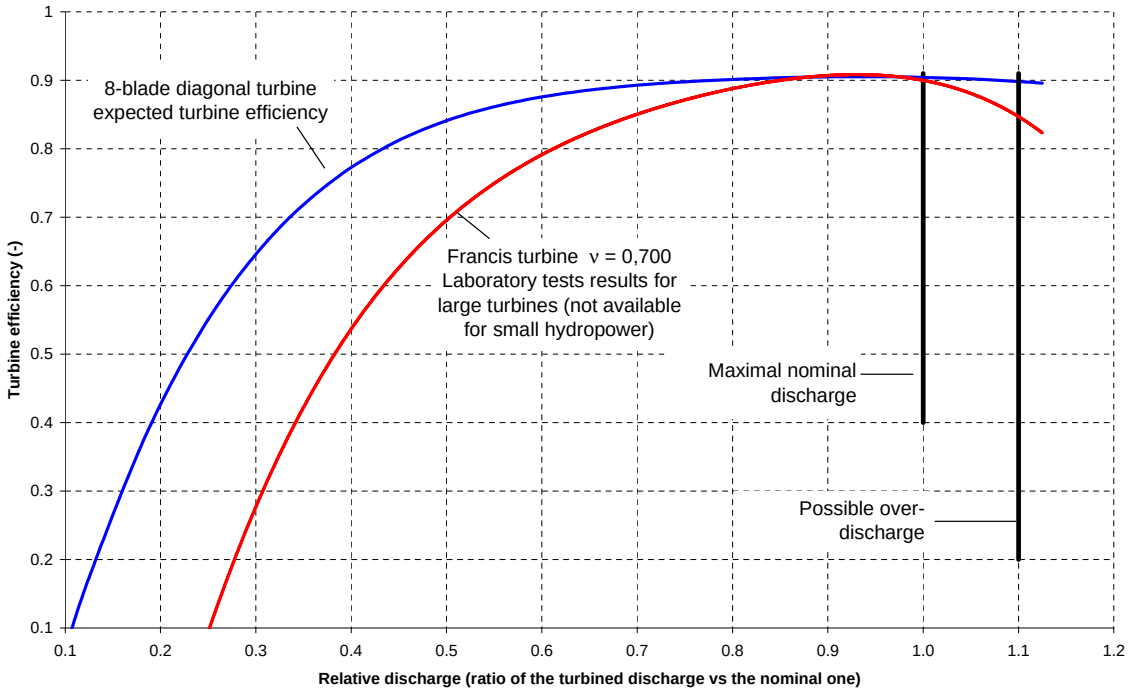
Francis / Diagonals – Efficiency flexibility



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Francis / Diagonals – model/prototype homology

- Diagonal runner = exact transfer of the scale model-design to the prototype (especially for the CNC manufactured blade)

Francis runner – buckets assembling

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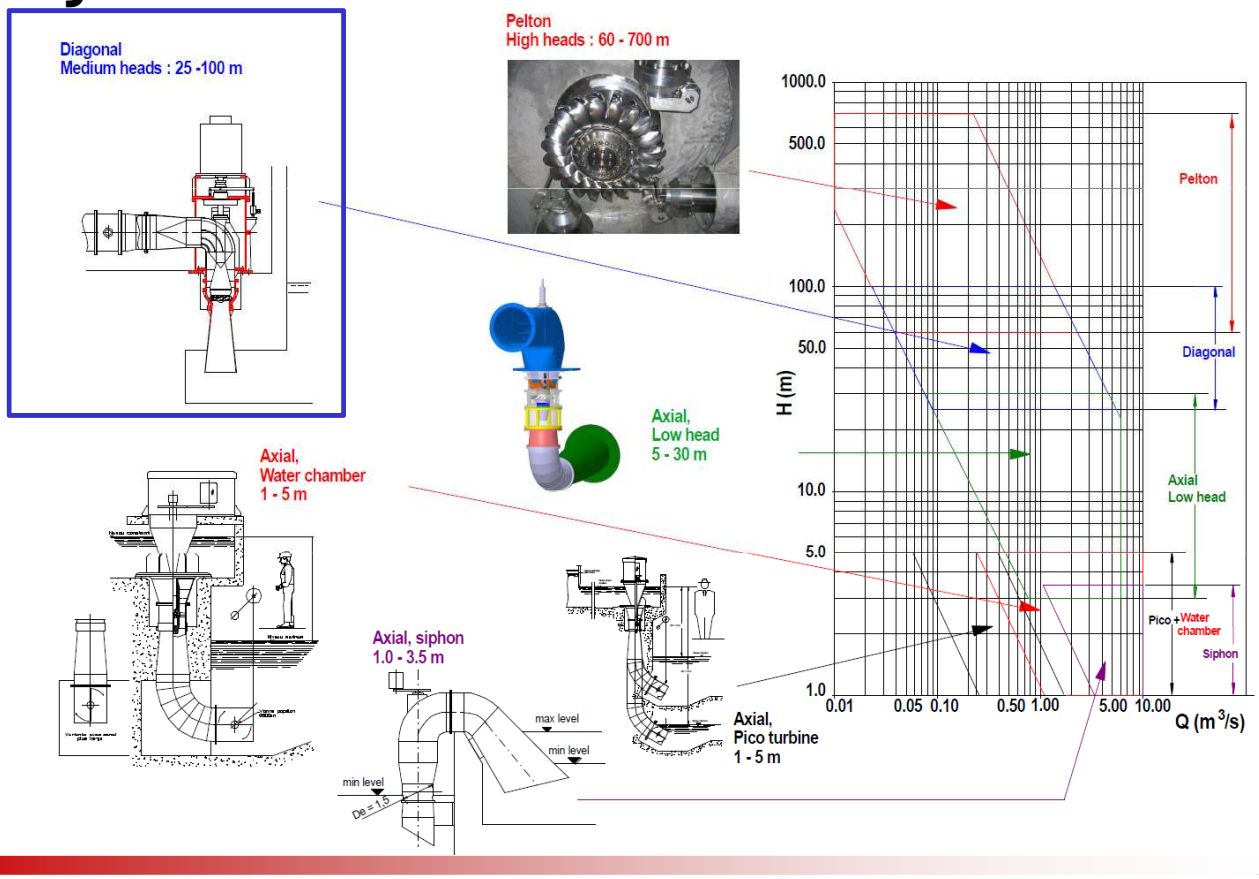

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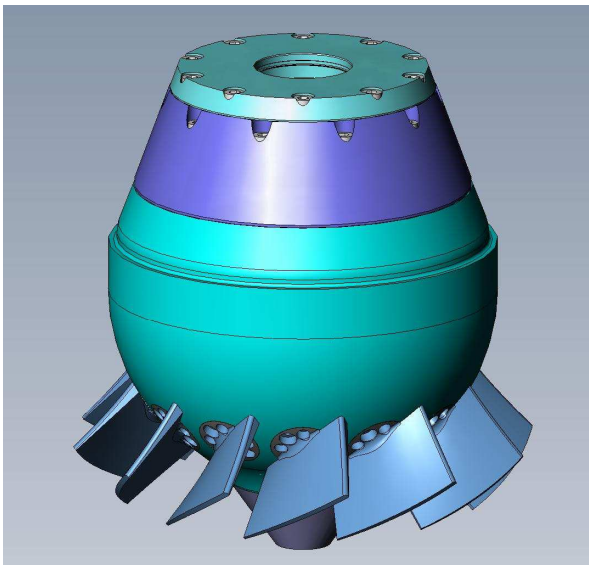
Project scope

- Project period: 2008-2011
- National fundings:
  - Swisselectric Research
  - Services Industriels de Genève,
  - Federal Office for Energy, OFEN



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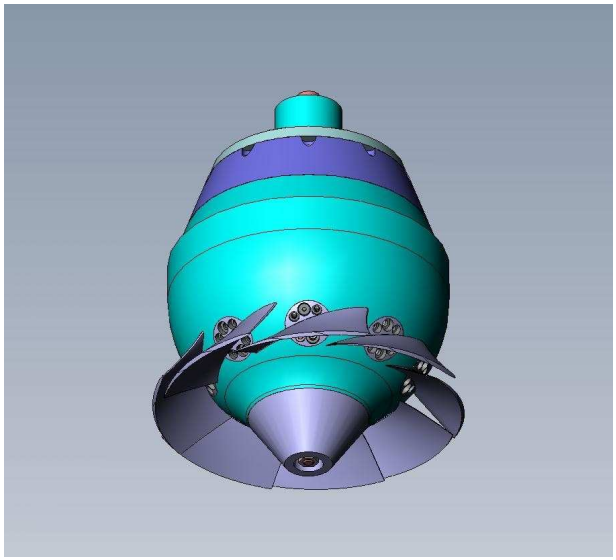
Objective: for an optimal use of the water resource

- high & guaranteed performances,
- reliability & manufacturing simplicity for SMEs
- competitive cost
- Low operation cost

cost efficiency



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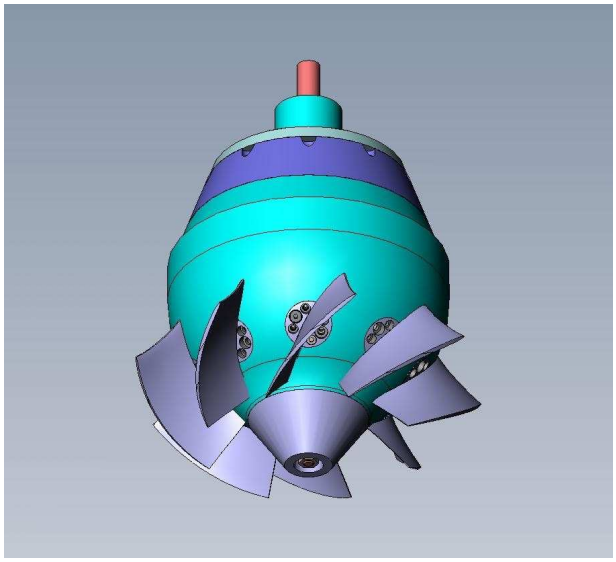
Guidelines

1. Modelling
2. Scale model, improved on MHyLab's test bench
3. Systemisation to cover heads between 25 and 100 m with 8, 10 or 12 adjustable blades
4. Dissemination to manufacturers: hydraulic profiles (one site, one turbine) + performances guarantees



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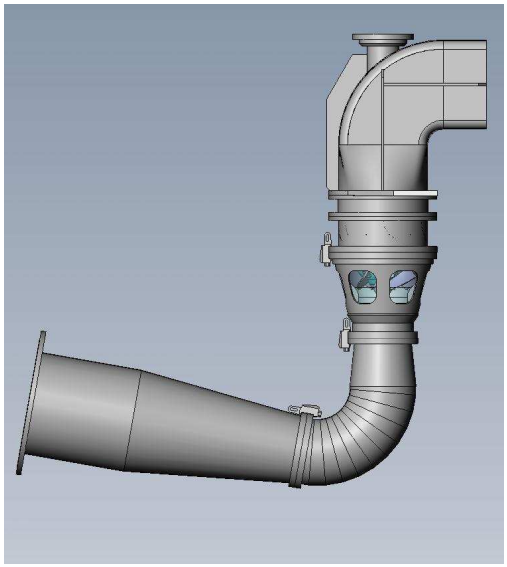
MHyLab Diagonal turbine

- Development of the axial turbine:
  - S shape
  - Square section inlet
  - Fixed conical guide vane
- 8 to 12 adjustable blades (de 25 à 100 m)



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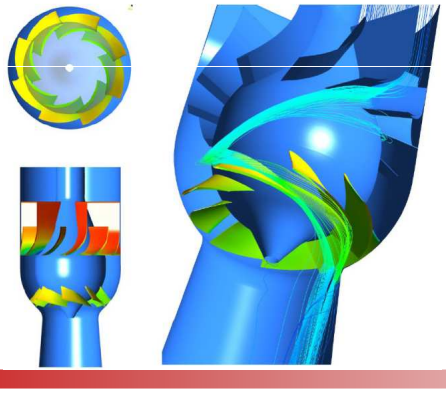
Diagonal modeling

Modeling achieved by the Lucerne University of Applied Sciences and Arts, HSLU (CH)



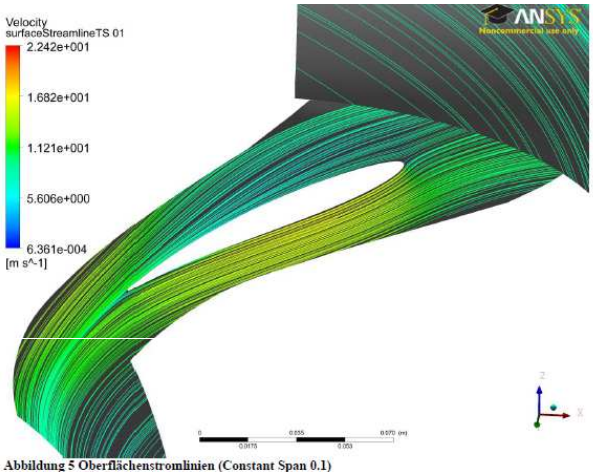


Abbildung 5 Oberflächenstromlinien (Constant Span 0.1)

Blade modelling – pressure distribution

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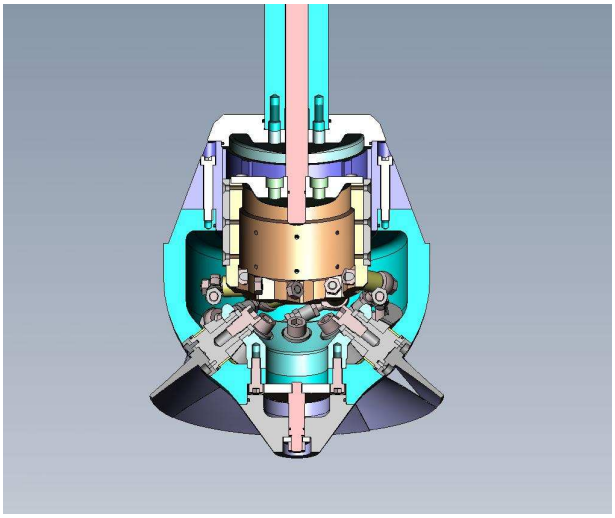
Blades drive system

Objective:

- To open & close the blades
- To assemble and disassemble the runner
- Challenges:
  - 8 to 12 blades
  - Inclined axis
  - Hub diameter: 165 mm



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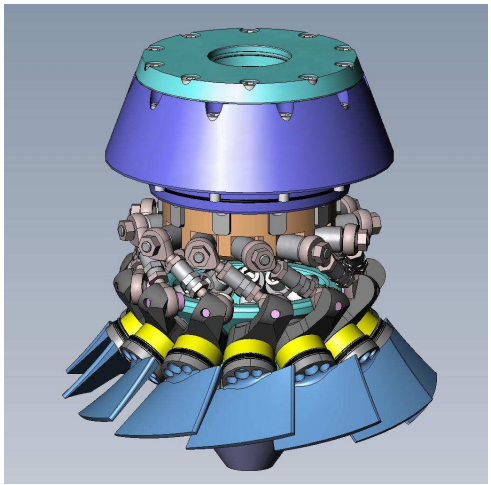
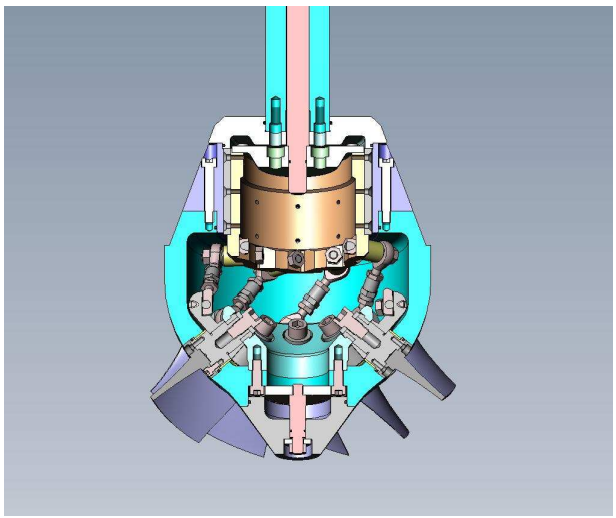
Blade drive system: levers and connecting rods



12 blades



8 blades

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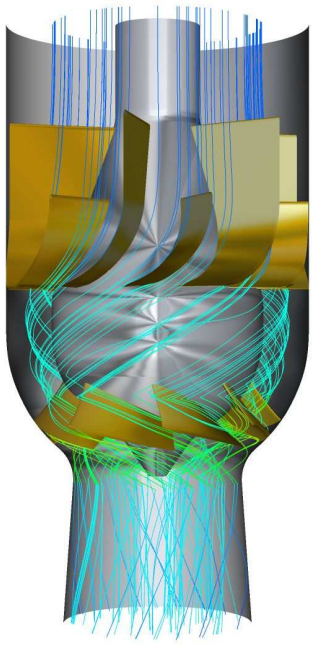
Planning

- Achieved:
  - Modelling + hydraulic & mechanical design
- Currently:
  - 8-blade scale model manufacturing
- Next:
  - Tests in laboratory for 8 blades and then 12 blades



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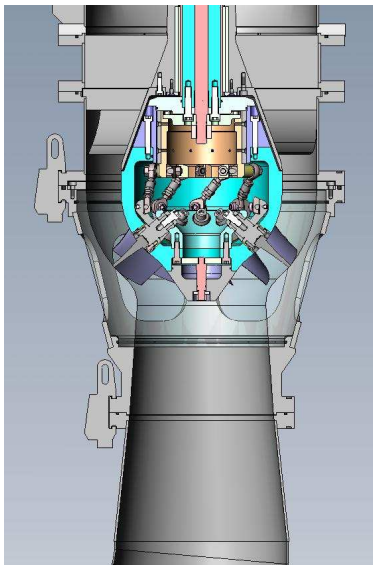
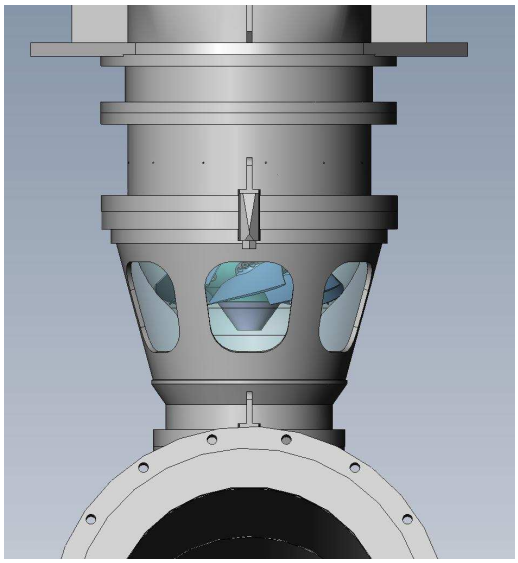
Conclusions

- Potentials:
  - Old Francis rehabilitations
  - Reserved flow at the foot of large dams
  - 30% of the remaining European potential (38 TWh/year)
- New know-how for SHP
- R&D still running in SHP
- Optimal use of the water resource
- Hidroenergia June 2010 Lausanne



To know more



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