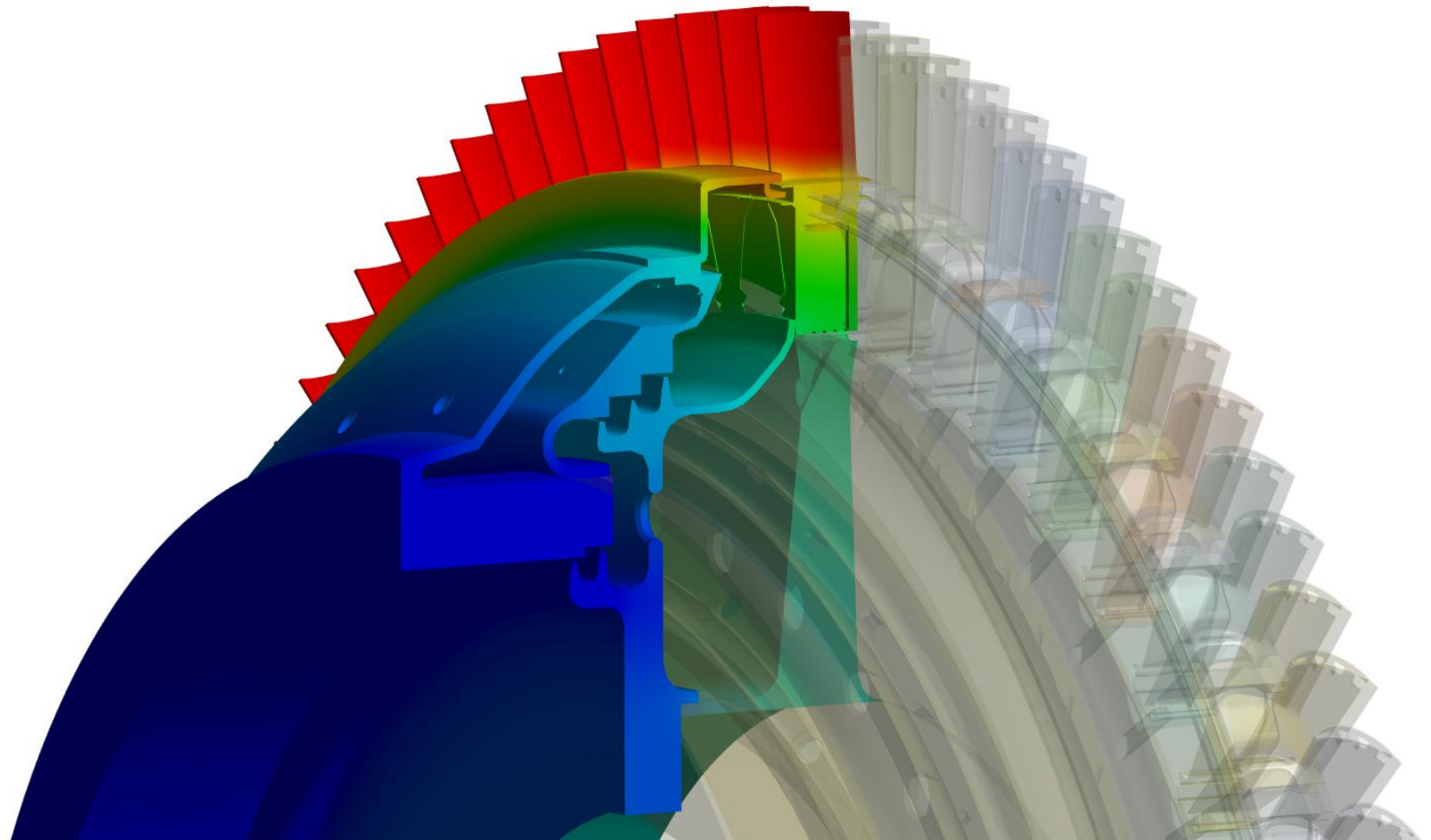
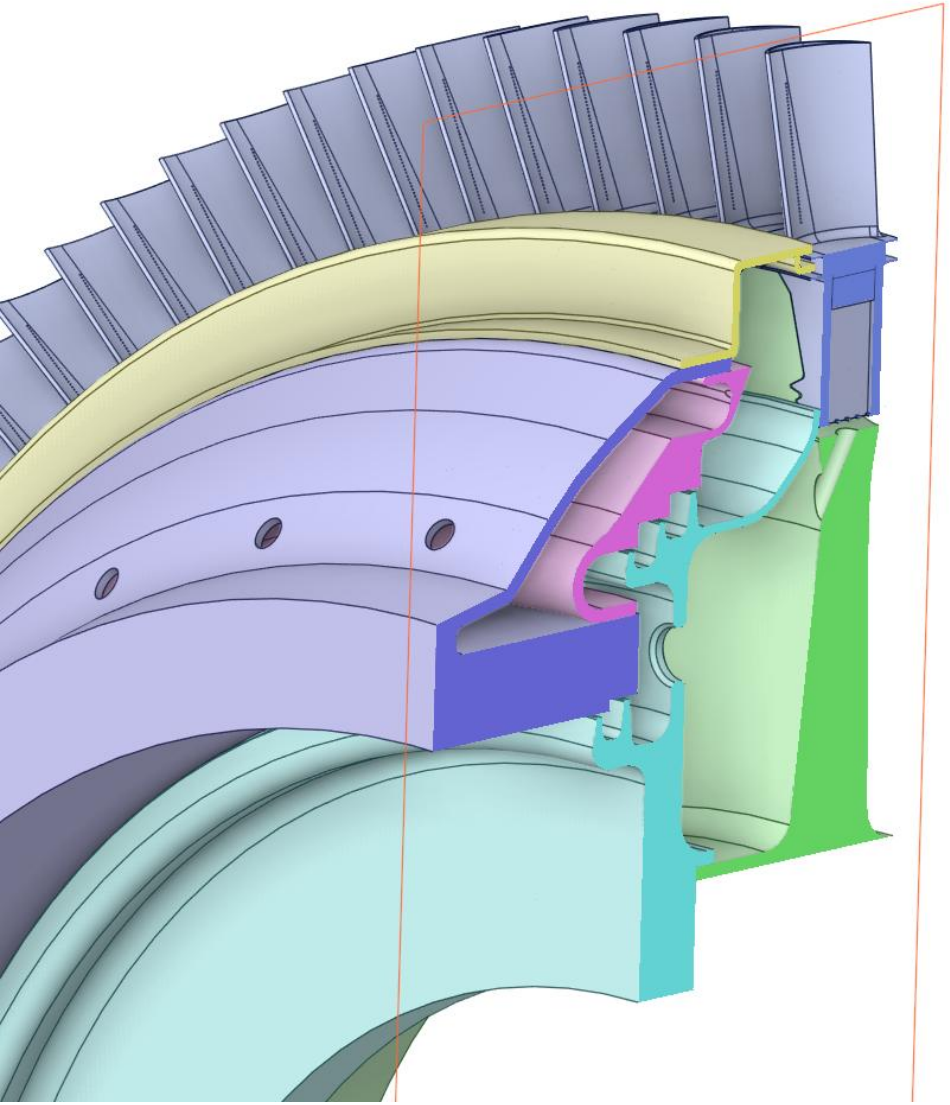
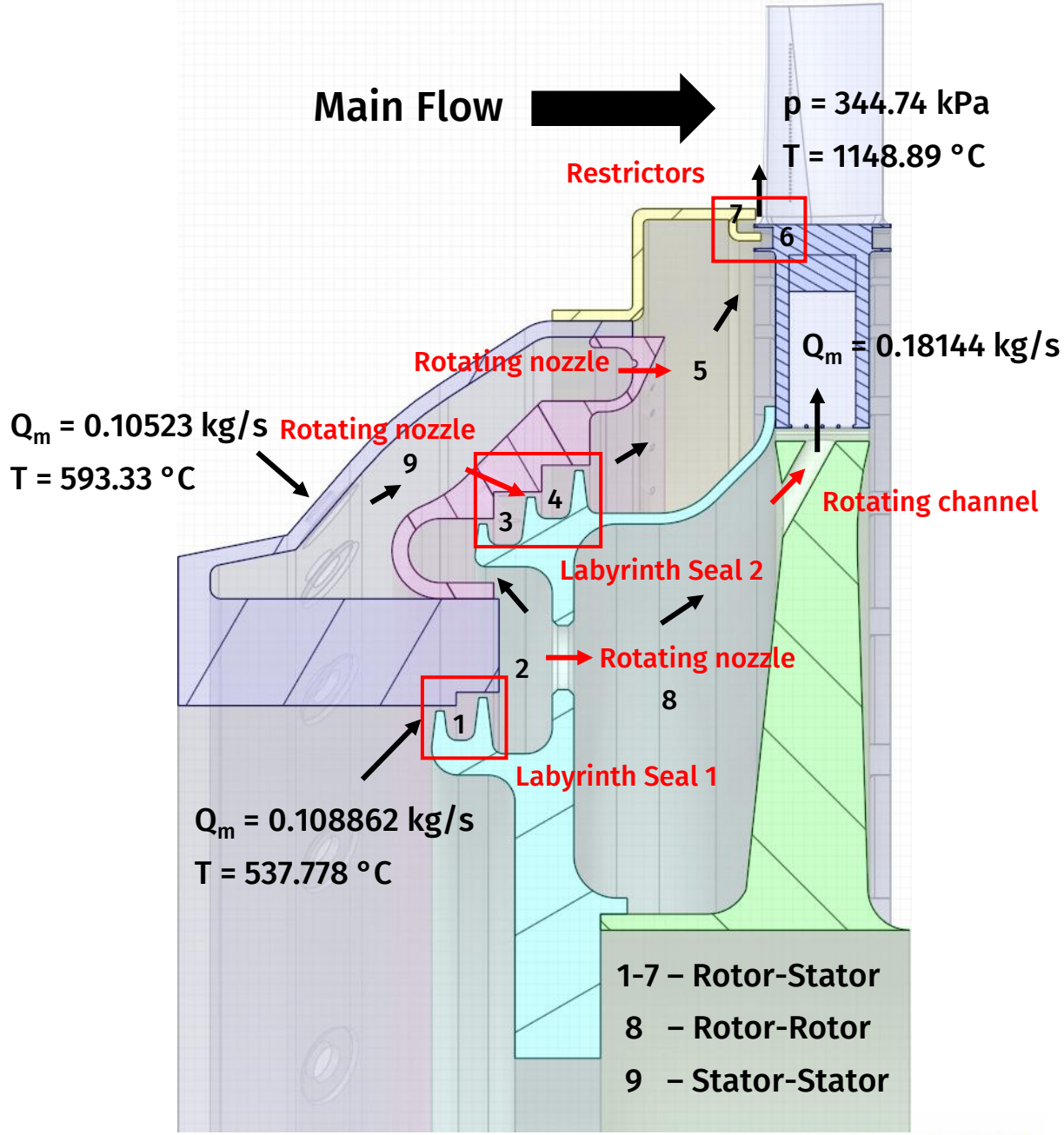
Výpočty proudění spárami u rotačních strojů



SVS FEM

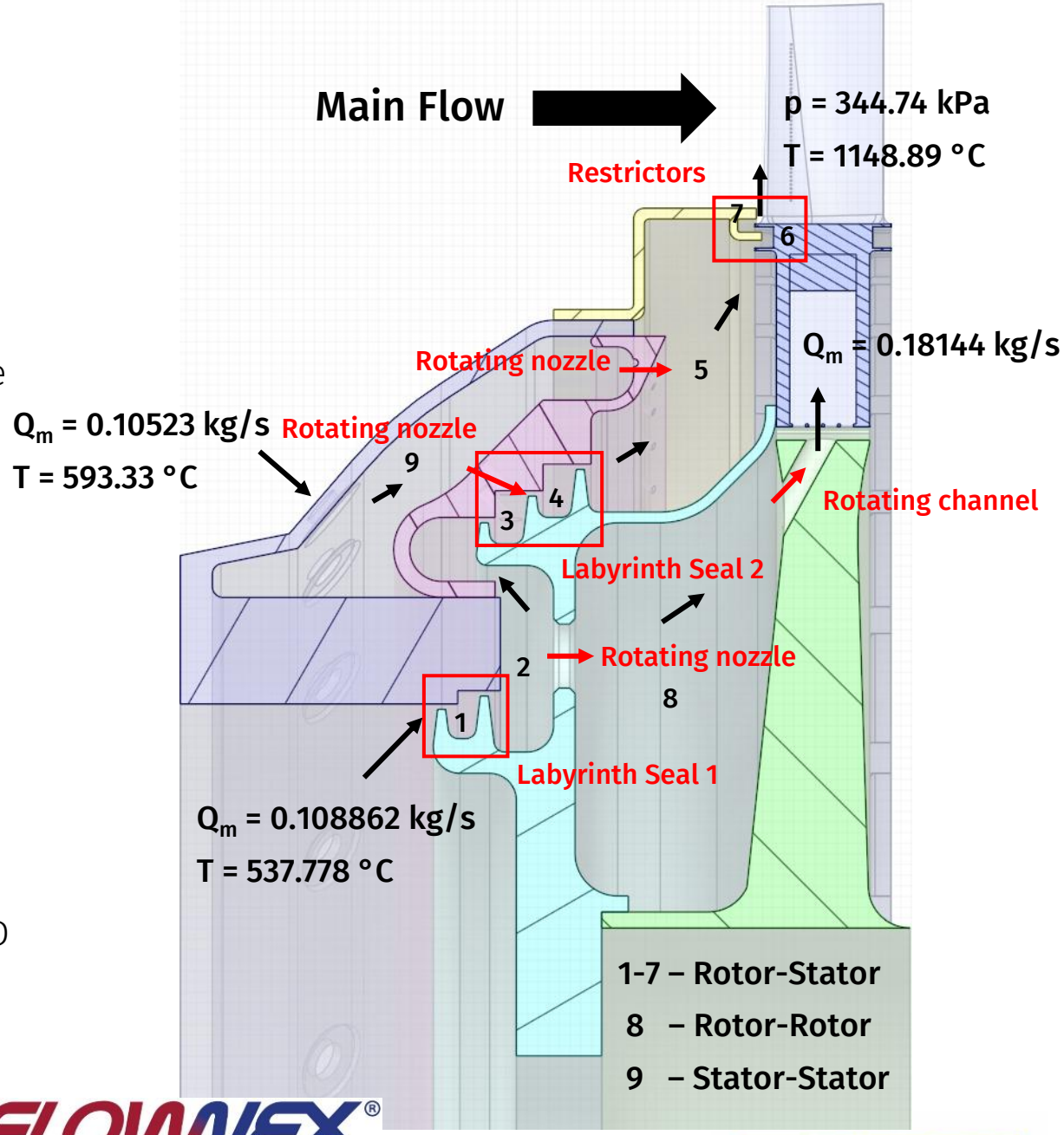
Zadání




Main Flow
p = 344.74 kPa
T = 1148.89 °C
Restrictors
7
6
Rotating nozzle
5
Q_m = 0.18144 kg/s
Q_m = 0.10523 kg/s
T = 593.33 °C
Rotating nozzle
9
4
3
Rotating channel
Labyrinth Seal 2
2
Rotating nozzle
8
1
Labyrinth Seal 1
Q_m = 0.108862 kg/s
T = 537.778 °C
1-7 – Rotor-Stator
8 – Rotor-Rotor
9 – Stator-Stator

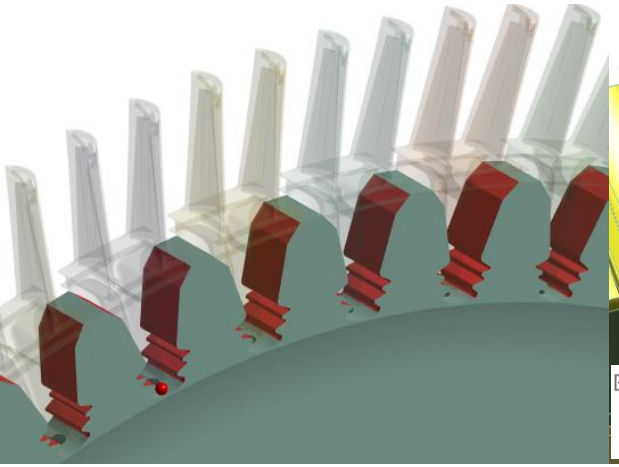
Zadání

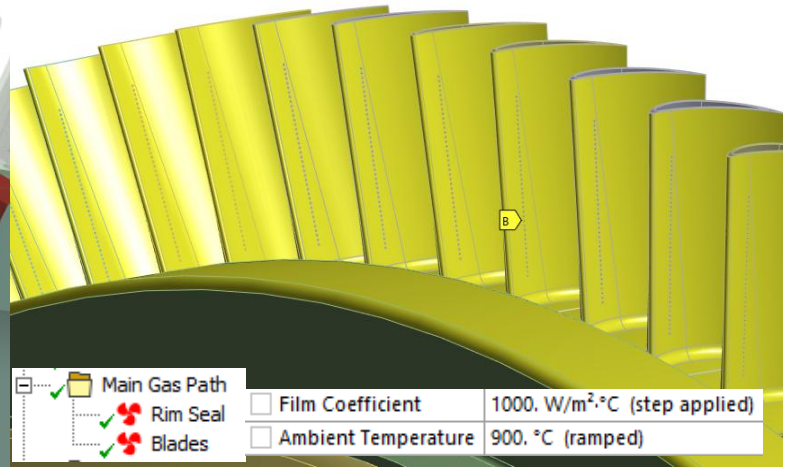
- Rozbor
  - Sekundární vzduchový systém, slouží především k chlazení a utěsnění vysokotlaké turbíny (první řady lopatek hned za spalovací komorou).
  - Teplota spalin za spalovací komorou výrazně překračuje teplotu tání materiálu turbínových lopatek a disků.
  - Predikce teploty pro zajištění pevnosti a životnosti komponent.
- Simulace
  - 3D analýza možná, ovšem časově náročná.
  - 1D analýza umožňuje efektivní výpočet rotujícího proudění ve spárách (software Flownex)
  - Swirl Solver v rámci Flownexu řeší dodatečnou rovnici zachování momentu hybnosti, čímž určuje tangenciální rychlost (swirl) v závislosti na poloměru, rotaci stěn a přenosu momentu.
  - 1D analýza lze propojit s 3D výpočtem proudění nebo 3D termální analýzou.
  - 1D model sekundárního vzduchového systému lze vytvořit přímo z prostředí Ansys Mechanical (ACT).

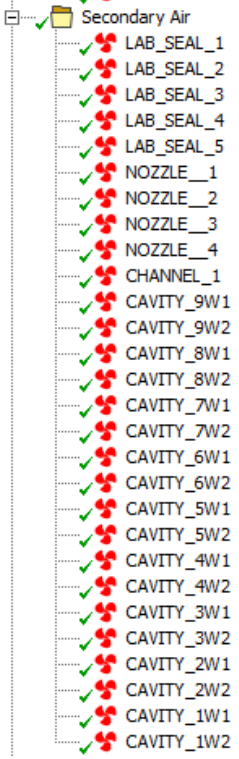


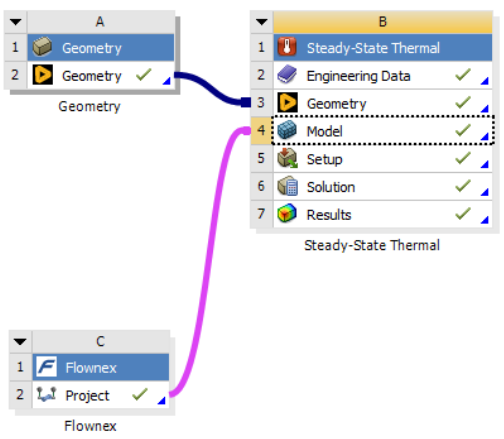
3D termální analýza

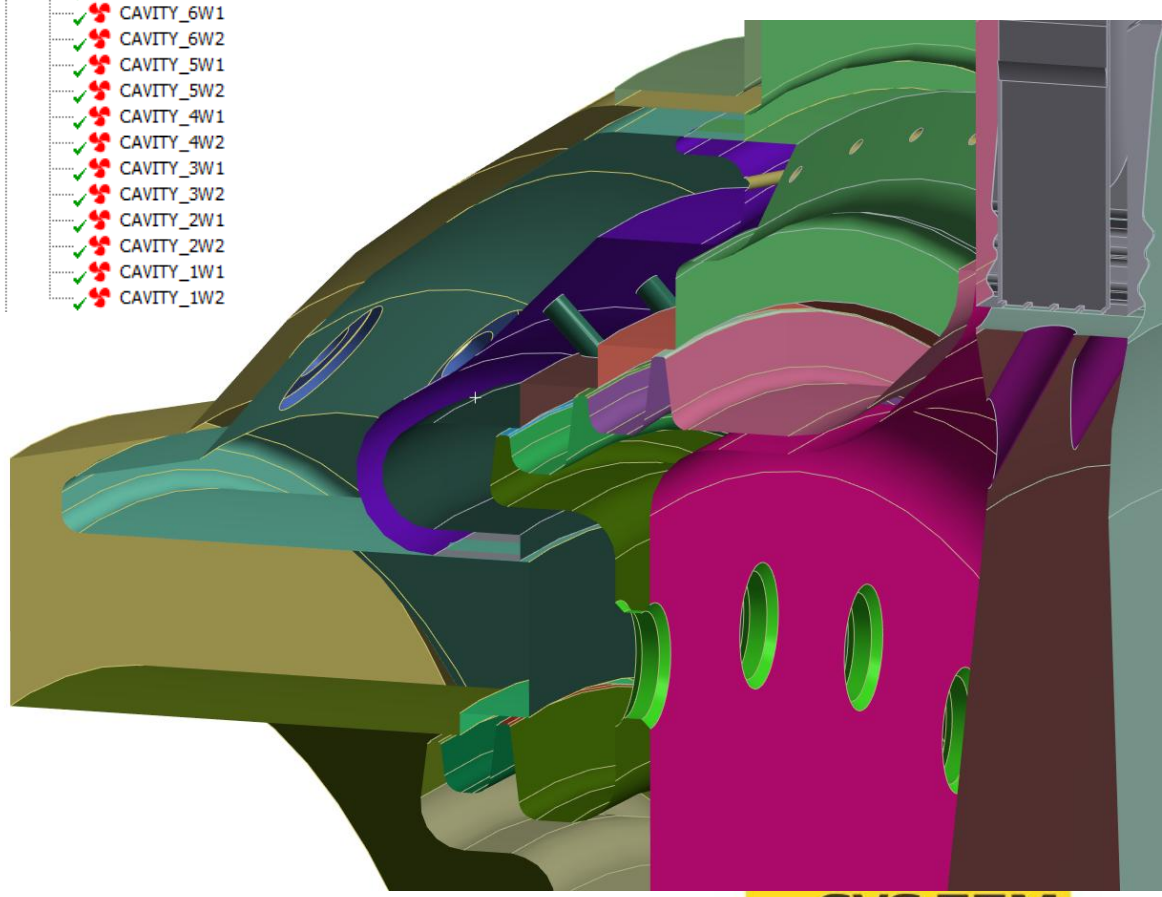
- Structural Steel
- Bonded kontatky
- Konvekce na plochách v kontaktu s hlavním proudem
- Konvekce na vnitřních plochách propojené s Flownexem



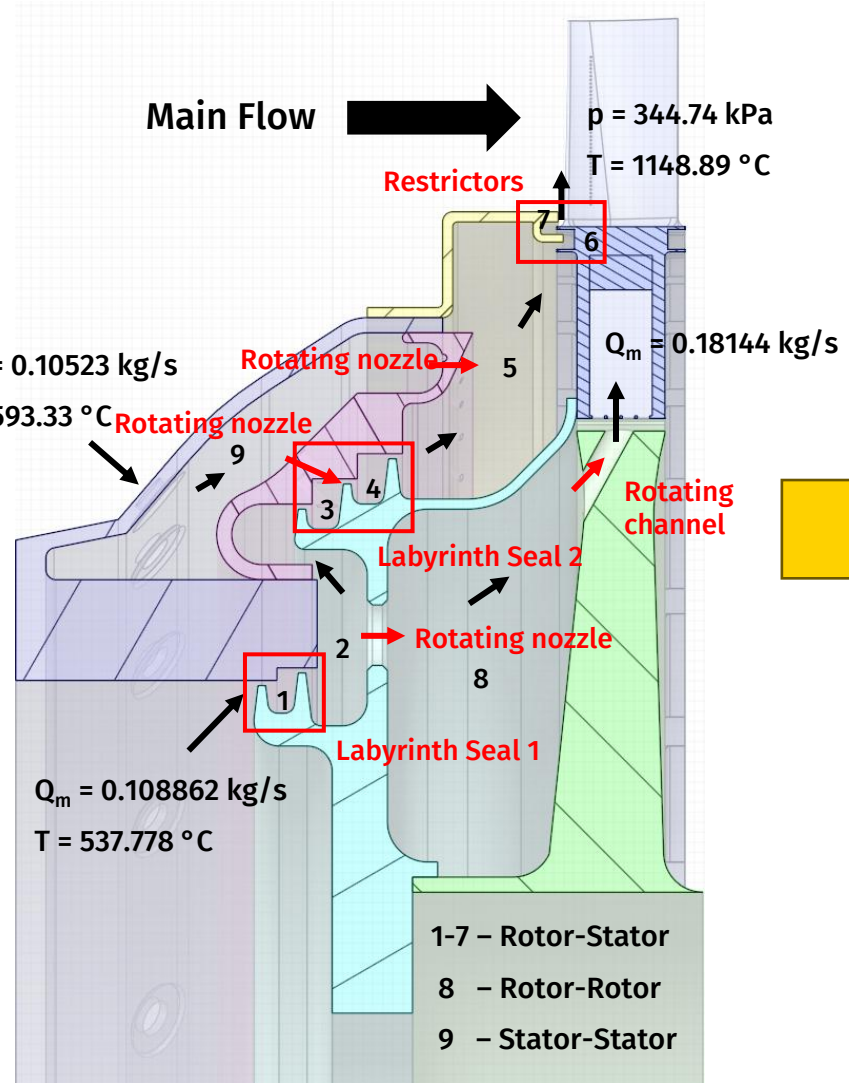


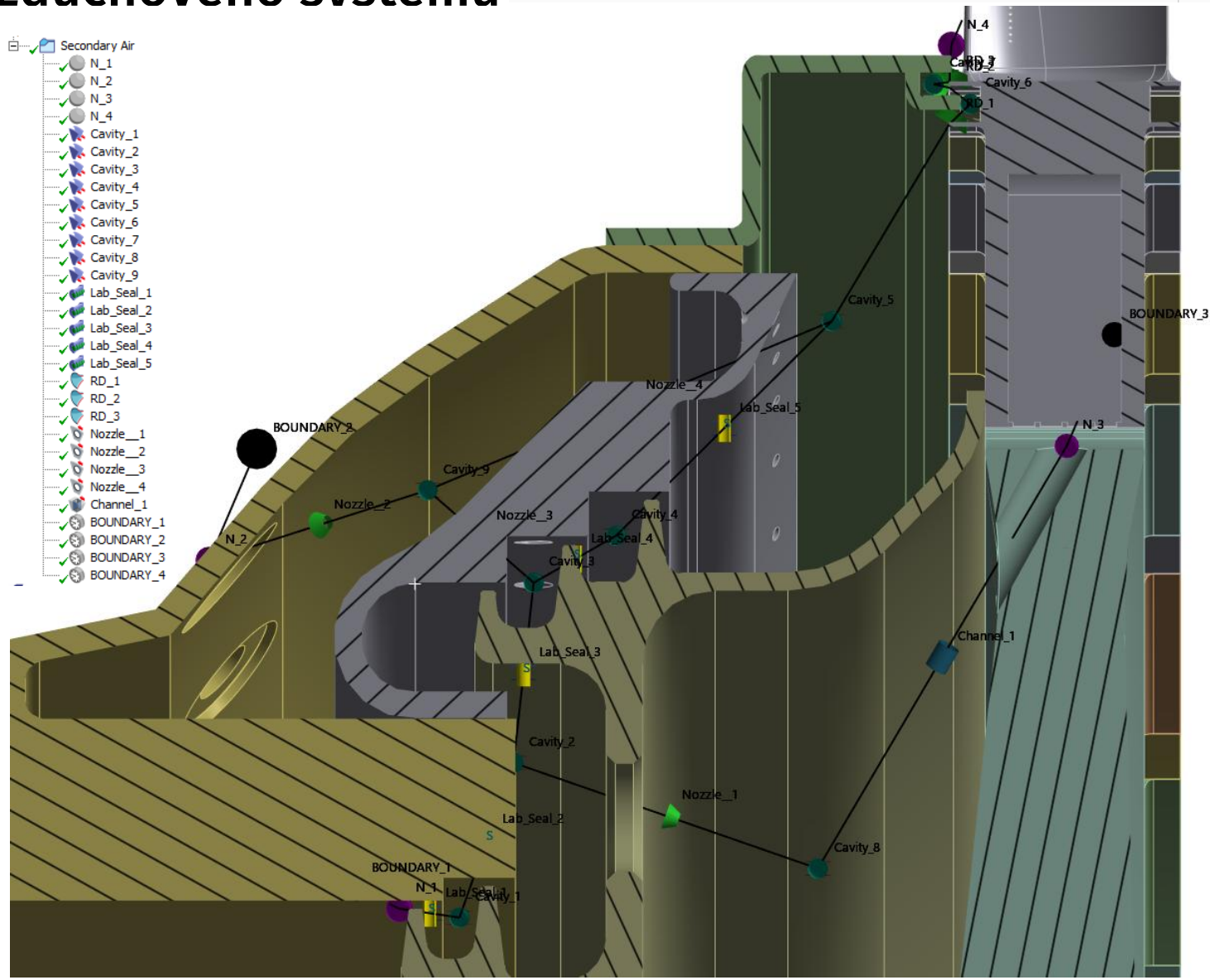






1D CFD sekundárního vzduchového svstému





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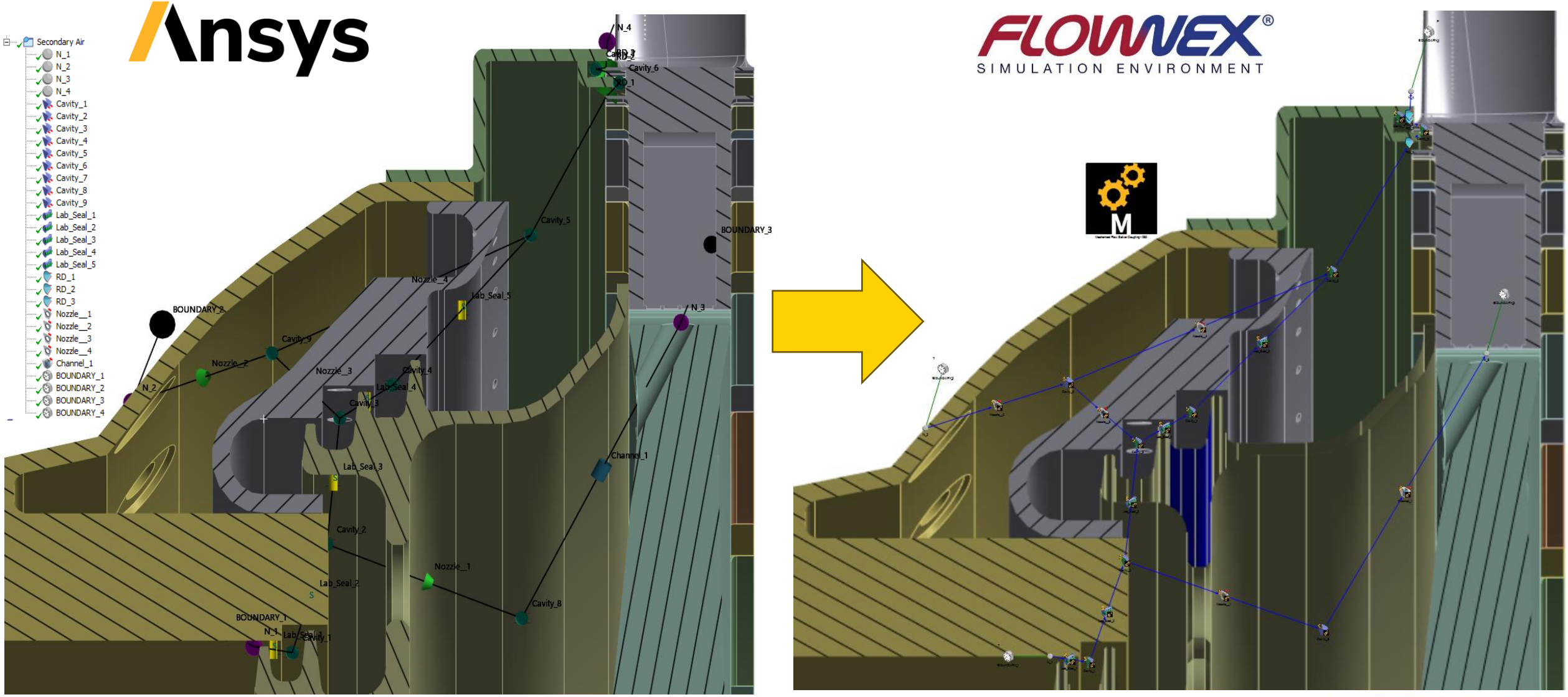
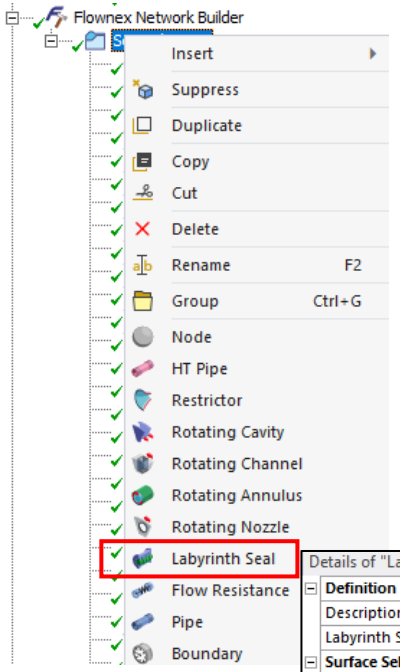
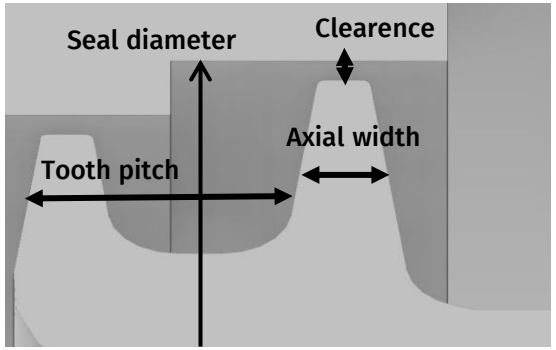
1D CFD sekundárního vzduchového systému



SVS FEM

1D CFD sekundárního vzduchového systému



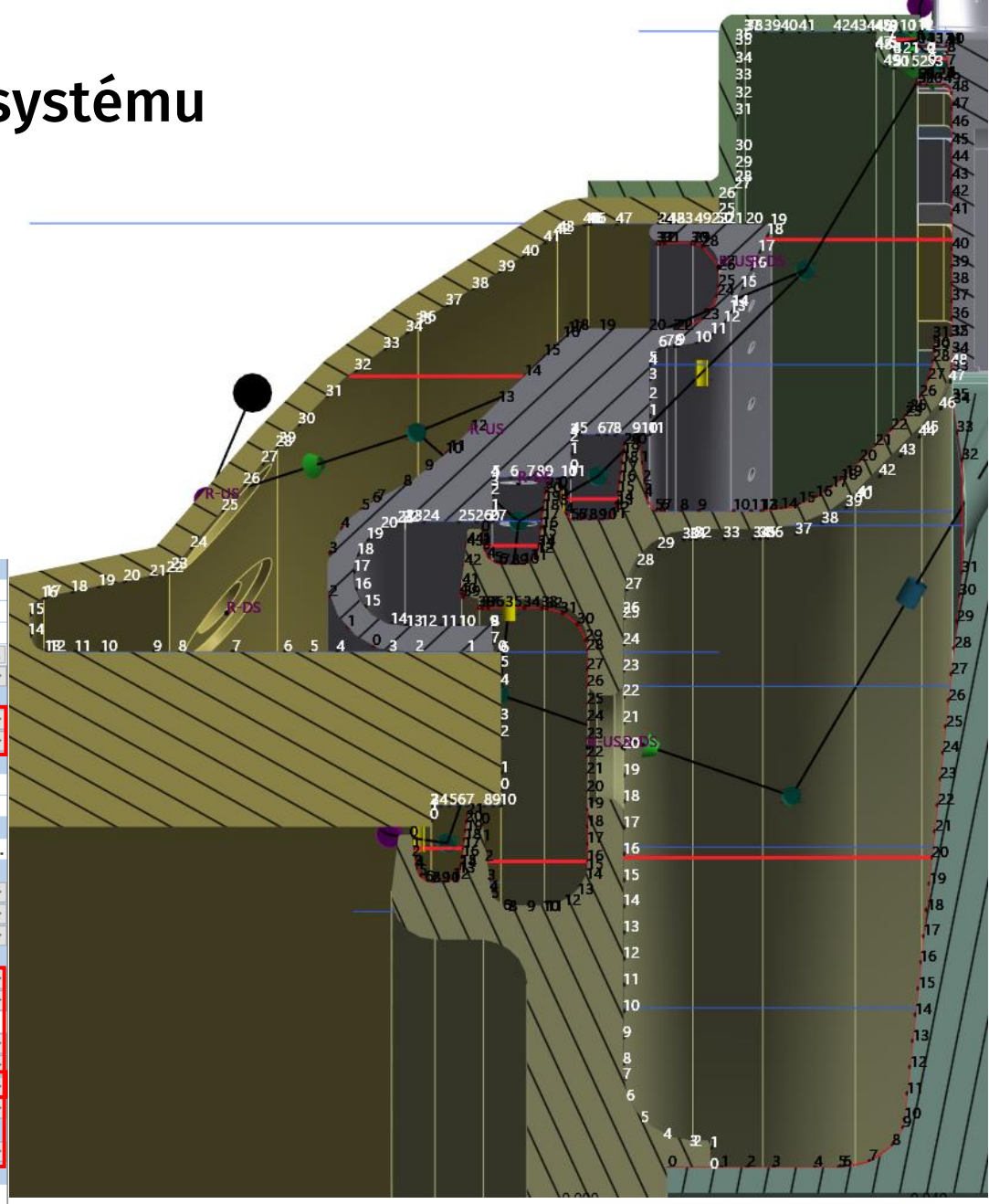


Details of "Lab_Seal_2"

Definition	
Description	Labyrinth Seal
Labyrinth Seal Type	
Surface Selection	
Scoping Method	Named Selection
Named Selection	LAB_SEAL_2_S
Fluid Selection	
Increment Using Fluid Elements	No
Inputs	
Seal Orientation	Axial
Rotation Speed	Rotation Speed A
Tooth Axial Width Mode	Selection
Tooth Axial Width	2 Faces
Tooth Pitch Mode	Selection
Tooth Pitch	2 Faces
Tooth Clearance Mode	Fixed
Tooth Clearance	2 Faces
Diameter Mode	Manual
Manual Seal Diameter	0.437 m
Number of teeth	1
Nodes	
Upstream	Cavity_1
Downstream	Cavity_2

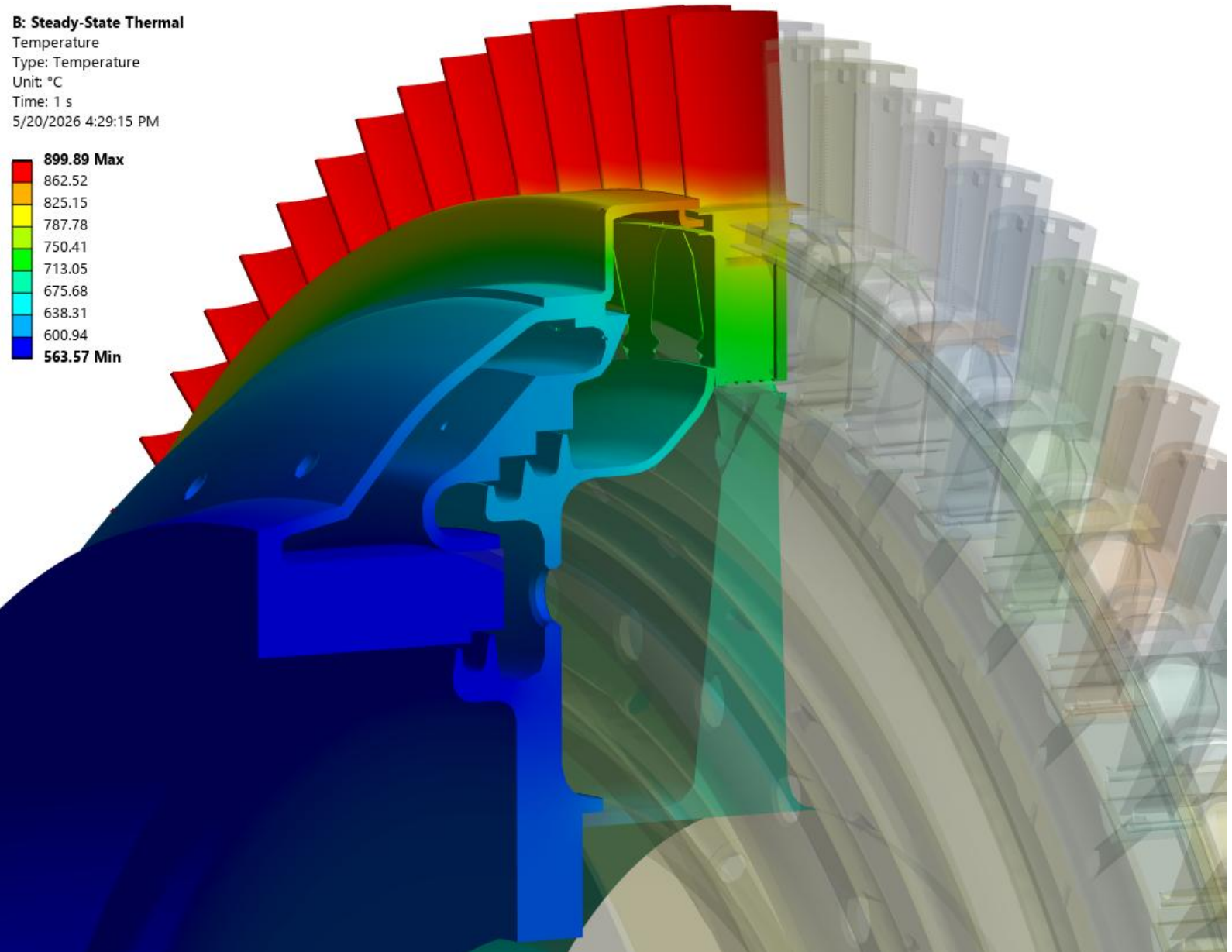
General		
Identifier	Lab_Seal_2	
Solving	☑	
Description		
Named selection	LAB_SEAL_2_S	
Tooth clearance mode	Fixed	
Convection Heat Transfer		
Heat transfer area	0.0638108	m²
Surface temperature	570.063	°C
Connected Nodes		
Upstream node	Rotor-Stator Cavity - 92	
Downstream node	Rotor-Stator Cavity - 81	
Fluids		
Fluid data reference	Air| Gases (Pure Fluids) (...	
Model		
Kinetic energy coefficient ...	Flat symmetrical jet equa...	
Discharge coefficient option	Sharp edge equation	
Model type	Discretised	
Geometry		
Seal type	Straight	
Seal orientation	Axial	
Number of teeth	1	
Tooth axial width	0.00239553	m
Tooth pitch	0.00828454	m
Tooth clearance	0.000898376	m
Seal diameter	0.437	m
Operational inputs		
Speed	3600	rpm
Fixed Options		
Prevent flow reversal	☐	
Fixed mass flow	☐	
Swirl Parameters		
Swirl transfer option	Calculate	

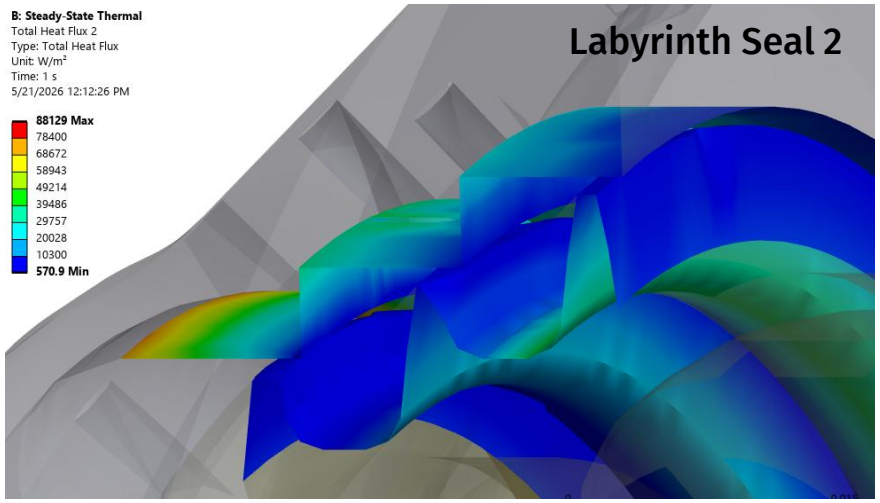
Konstantní vzdálenost (lze dynamicky upravovat s ohledem na deformaci)



SVS FEM

Výsledky - Ansys

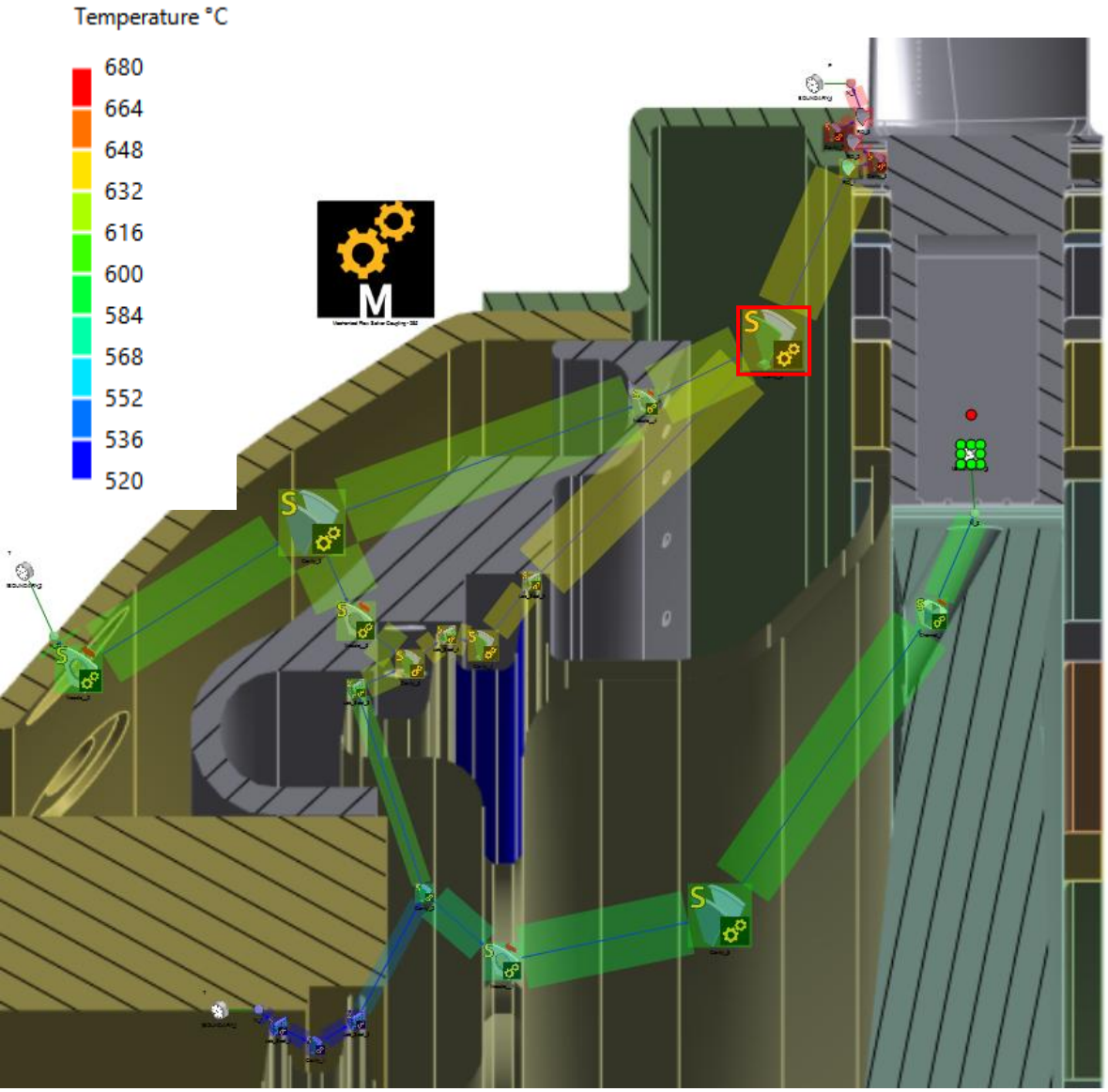


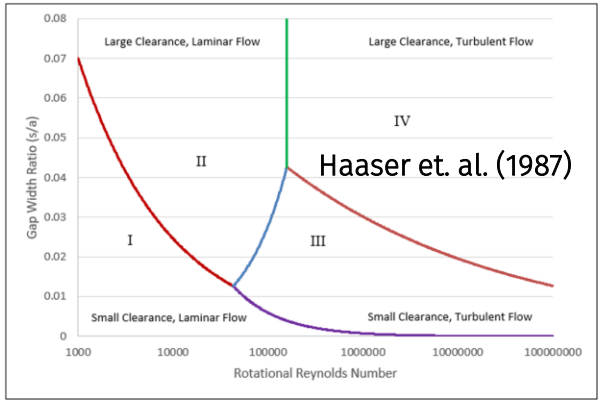


Waiting for data from Flownex. 3600s until timeout.

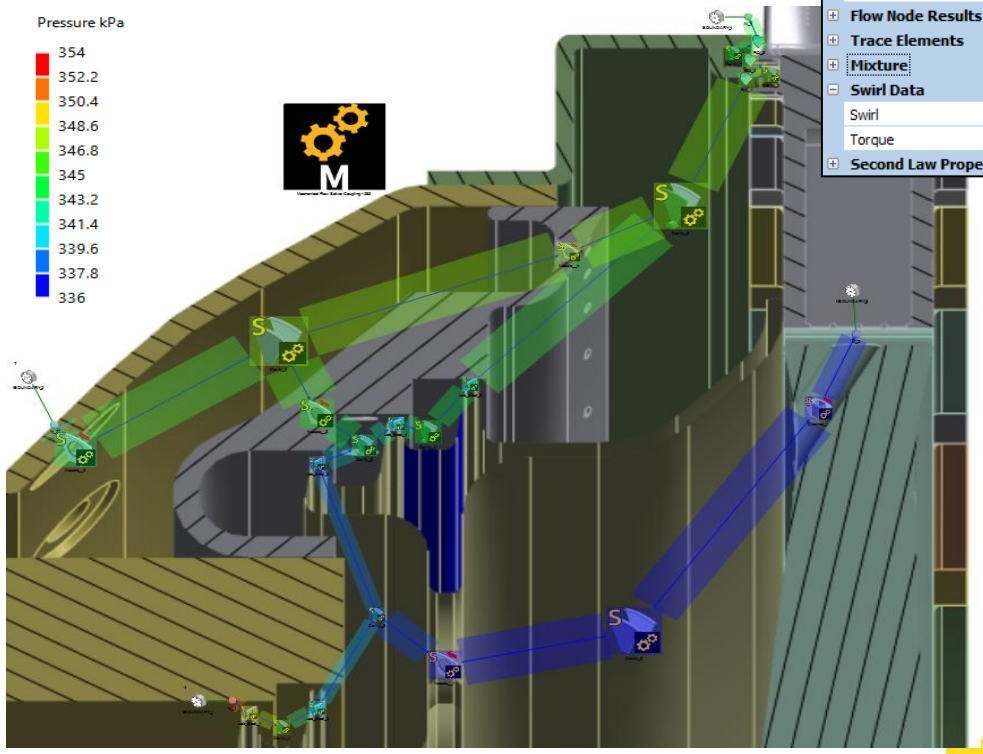
Surface	HTC	Fluid Temp
CAVITY_9_W2S	257.5	0.604075421E+003
CAVITY_9_W1S	257.7	0.604084256E+003
CAVITY_8_W2S	35.07	0.588929453E+003
CAVITY_8_W1S	23.07	0.588876859E+003
CAVITY_7_W2S	9.704	0.669093796E+003
CAVITY_7_W1S	361.6	0.674219224E+003
CAVITY_6_W2S	77.36	0.666975881E+003
CAVITY_6_W1S	298.2	0.670060780E+003
CAVITY_5_W2S	92.96	0.642299655E+003
CAVITY_5_W1S	263.3	0.644307462E+003
CAVITY_4_W2S	149.1	0.639256160E+003
CAVITY_4_W1S	170.0	0.639087886E+003
CAVITY_3_W2S	127.1	0.629595776E+003
CAVITY_3_W1S	195.4	0.630085139E+003
CAVITY_2_W2S	145.7	0.586363463E+003
CAVITY_2_W1S	158.5	0.586113608E+003
CAVITY_1_W2S	138.6	0.549916218E+003
CAVITY_1_W1S	166.8	0.549897948E+003
LAB_SEAL_1_S	464.1	0.537025577E+003
LAB_SEAL_2_S	455.0	0.549236727E+003
LAB_SEAL_3_S	152.0	0.628644196E+003
LAB_SEAL_4_S	137.8	0.638283702E+003
LAB_SEAL_5_S	153.6	0.641155353E+003
NOZZLE__1_S	206.6	0.584981978E+003
NOZZLE__2_S	239.8	0.596400910E+003
NOZZLE__3_S	228.5	0.603577232E+003
NOZZLE__4_S	121.8	0.604825135E+003
CHANNEL_1_S	715.4	0.583859289E+003

Výsledky - Flownex





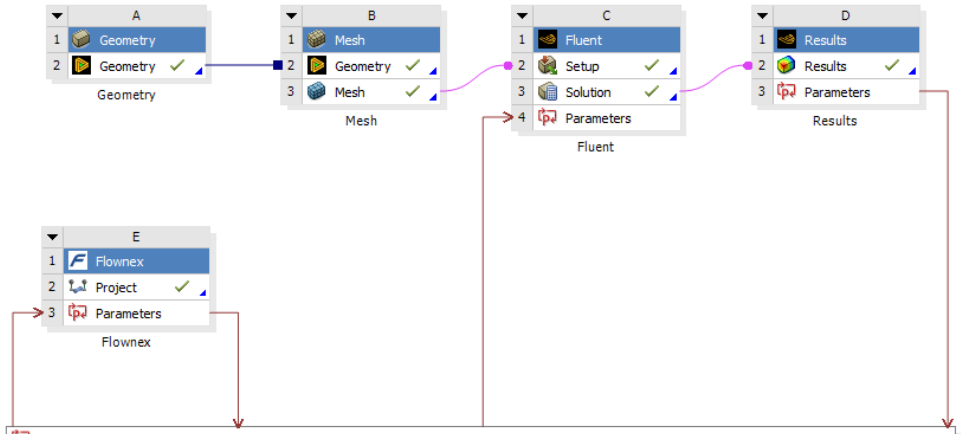
General		
Identifier	Cavity_5	
Description		
Heat Transfer Element Results		
Rotor convection coefficient	263.333	W/m².K
Stator convection coefficient	92.9582	W/m².K
Rotor average surface temperature	694.993	°C
Stator average surface temperature	719.459	°C
Rotor convection heat transfer	-2.10564	kW
Stator convection heat transfer	-1.26004	kW
Rotor-Stator Results		
Outer Radius Results		
Swirl ratio	0.264789	
Disk Reynolds number	1.14054E+06	
Windage power transfer	-0.33558	kW
Rotor moment	0.890155	N.m
Stator moment	-0.210697	N.m
Rotor bolts moment	0	N.m
Stator bolts moment	0	N.m
Net flow moment	-0.679457	N.m
Outer rotating shroud moment	0	N.m
Rotor-Stator flow regime	Flow Regime IV	
Inner radius	0.251985	m
Outer radius	0.30701	m
Flow Node Results		
Trace Elements		
Mixture		
Swirl Data		
Swirl	9.40885	m²/s
Torque	-0.890155	N.m
Second Law Properties		



Propojení na 3D CFD

Jednocestný coupling ve WB

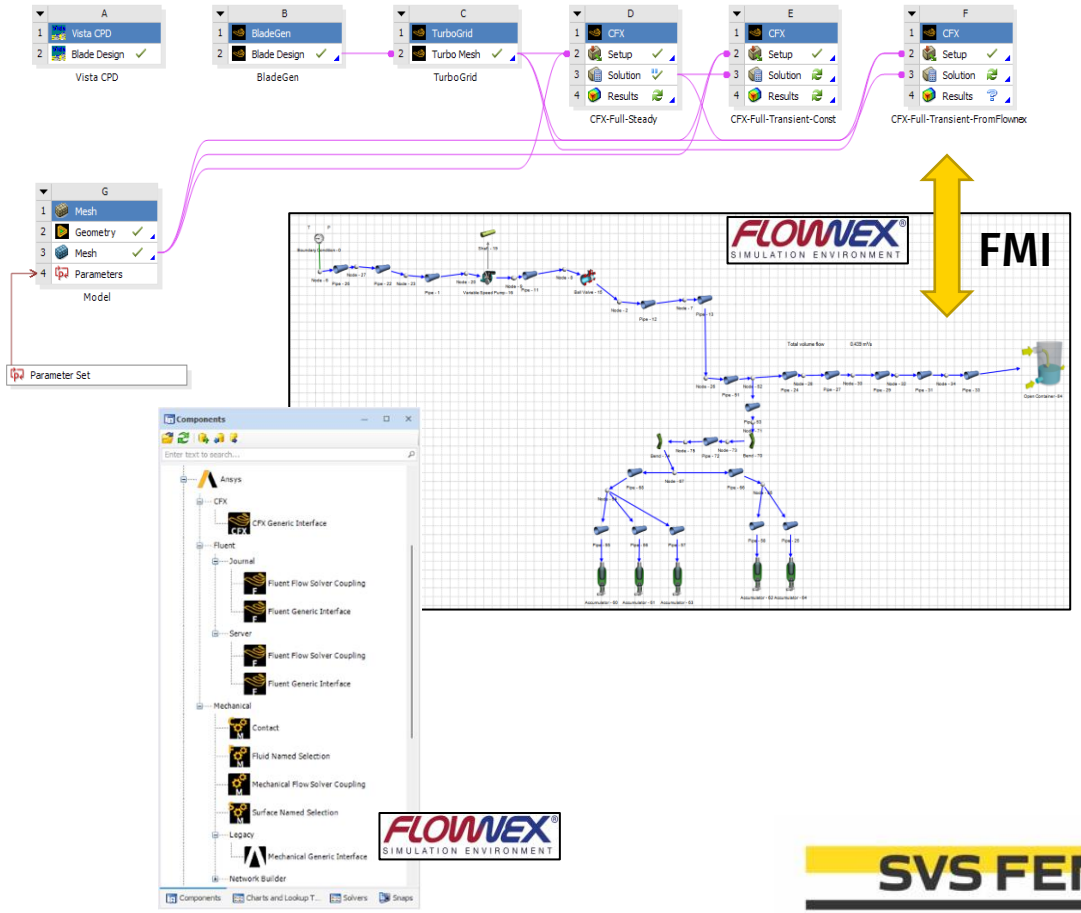
- Přes vázané parametry



	ID	Parameter Name	Value	Unit
2	Input Parameters			
3	Fluent (C1)			
4	P1	BendInletP	1.5314E+05	Pa
5	P2	MassFlowRate	10	kg s^-1
6	Flownex (E1)			
7	P5	Parameter Table 1\Opening	0.5	0-1
*	New input parameter	New name	New expression	
9	Output Parameters			
10	Results (D1)			
11	P3	dP	6.8594	Pa
12	P4	OutletP	1.5312E+05	Pa
13	Flownex (E1)			
14	P6	Parameter Table 1\Total pressure	153.14	kPa
15	P7	Parameter Table 1\Total mass flow	10	kg/s

Dvoucestný coupling

- Přes předpřipravené propojení ve Flownexu
- Přes rozhraní FMI



Díky za pozornost a zůstaňme ve spojení

Radim Burda