



ANDRITZ GROUP

TRASPORTO DI SEDIMENTO SOLIDO NEGLI IMPIANTI IDROELETTRICI. ESEMPI DI ANALISI, CONTROMISURE E GESTIONE

MARCO TARAVAN - SETTEMBRE 2021

ANDRITZ

ENGINEERED SUCCESS

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TRASPORTO SEDIMENTO SOLIDO

PRINCIPALI AREE NEL MONDO DOVE SI PRESENTA QUESTO PROBLEMA



Forrest Kerr
Montrose
East Toba
Kwalsa
Koma-Kulshan
.....

San Francisco
Agoyan
Coca Codo
.....

Moyopampa
Cerro del Aguila
Santa Teresa
.....

Coya
Sauzal
Alfalfal
Chacayes
La Higuera
Blanco
.....

Aletsch Mörel
Stalden
Bitsch
Ernen Pradella
Fionnay
Fulpmes
.....

Nathpa Jhakri
Malana Baspa
Teesta
Karcham Wangtoo
Visnupraya
.....



TRASPORTO SEDIMENTO SOLIDO



Speciali particelle, che sono più dure della superficie del materiale della turbina, sono la principale causa dell'erosione idro-abrasiva.

Già una concentrazione di particelle di **80 mg/l** (**0,08 kg/m³**) può causare considerevoli danni (dipende dal tipo di turbina).

Alcuni fiumi raggiungono una media di **2.000 mg/l** durante la stagione più piovosa ed è normale misurare picchi di **20.000 mg/l**

In India sono stati misurati valori di **80.000 mg/l**



EROSIONE IDRO-ABRASIVA > EFFETTI

CONSEGUENZE DEL FENOMENO



Modifiche alla geometria



Perdita di rendimento
Aggiunta danni per cavitazione
Sicurezza meccanica



Costi di riparazione

Diminuzione del TBO (time between overhaul – intervallo tra le manutenzioni)

Perdita nella produzione di energia

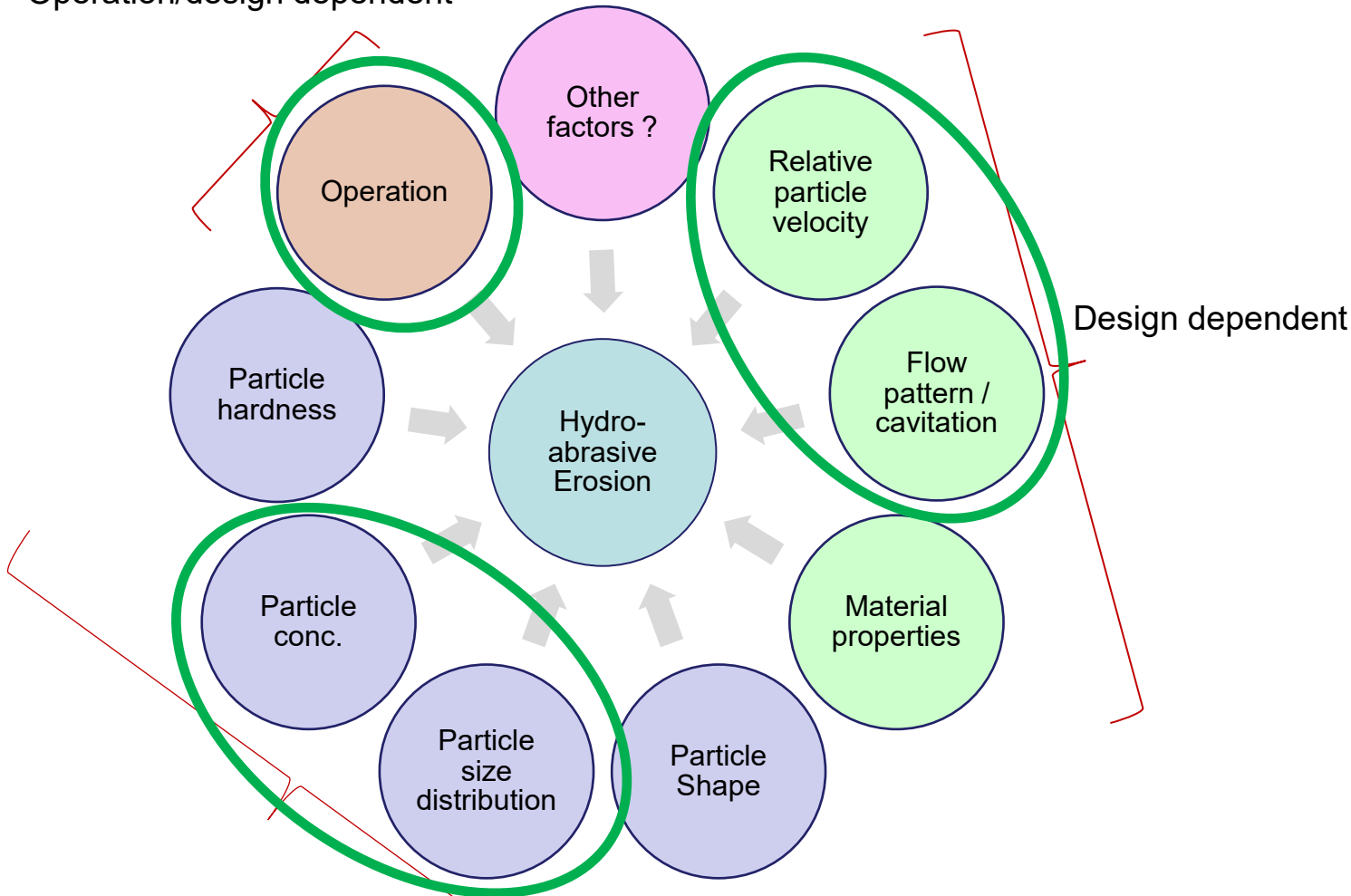
Perdita di sicurezza della centrale



AMBITI DI STUDIO



Operation/design dependent



Simulazione numerica

- Comprensione fisica del processo erosivo
- Turbolenza

Progettazione della turbina

- Scelta dei profili idraulici
- Angolo di impatto delle particelle

Modelli di riferimento

- Feedback da centrali idroelettriche esistenti

Cannot be influenced
Highly varying with time

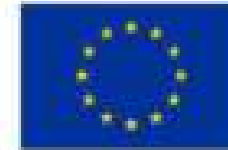
An EU collaboration project

- Grant Agreement for: **Initial Training Networks**
- Call Identifier: **FP7-PEOPLE-2013-ITN**
- Implementation Mode: **EID**
- Project Acronym: **PREDHYMA**
- Grant Agreement no.: **608393**

- Project full name: *Prediction of **Erosion** Damages in **Hydraulic Machines***

- Date of Approval: **6 June 2013**
- Project Start Date: **1 October 2013**
- Project End Date: **30 September 2017**

- Budget:  **M€**
- Coordinator: **ANDRITZ Hydro Switzerland**
- Resources: **4 PhD students (4x3 p.y)**



INSA

INSTITUT NATIONAL
DES SCIENCES
APPLIQUEES
LYON

ANDRITZ
Hydro

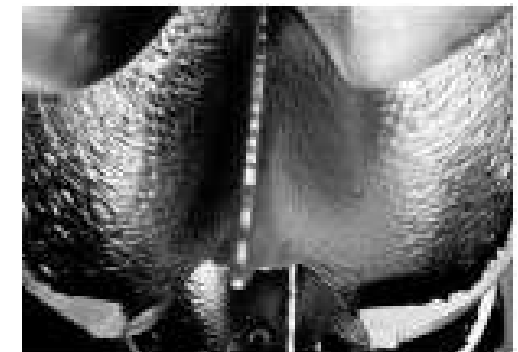


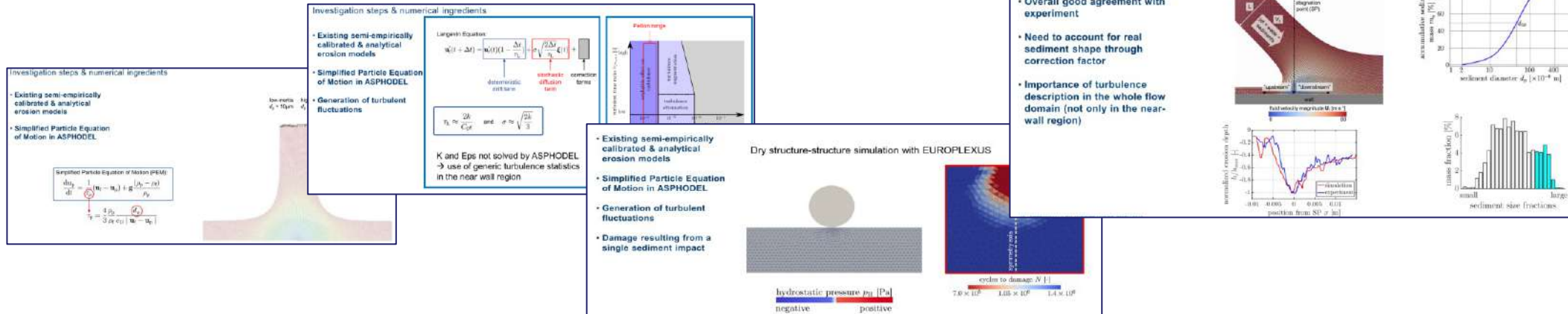
Research methodology

Use direct simulation / first principles to compute damaging arising from:

- Impacts of gravels and stones
- **Hydro-abrasive erosion**
- Cavitation erosion
- Erosion from droplets impacts

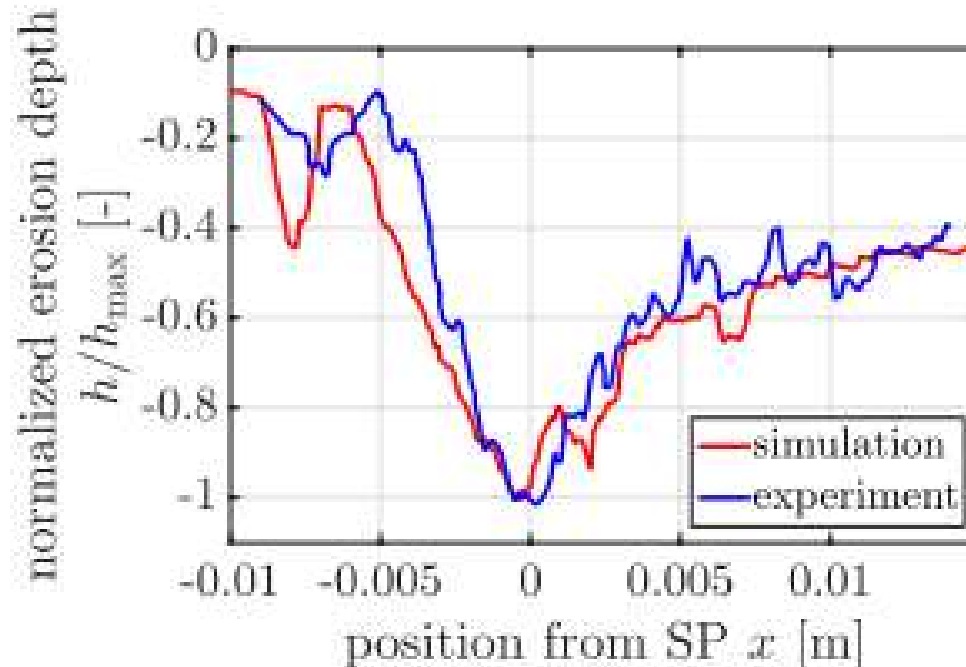
<http://predhyrna.ec-lyon.fr/>





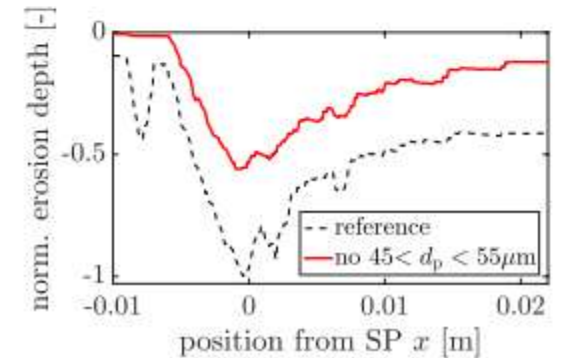
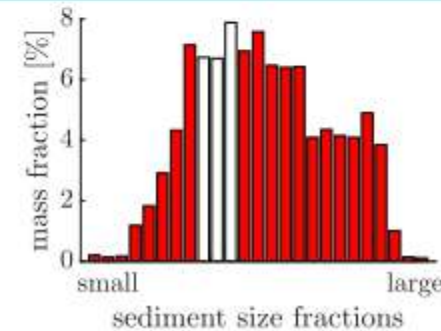
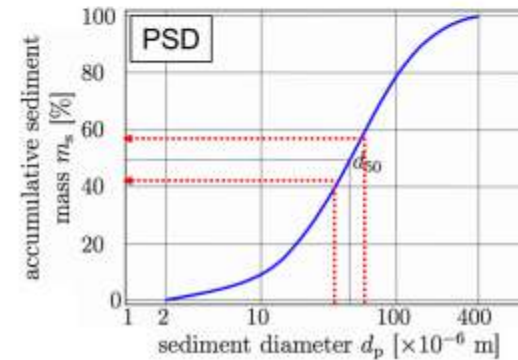
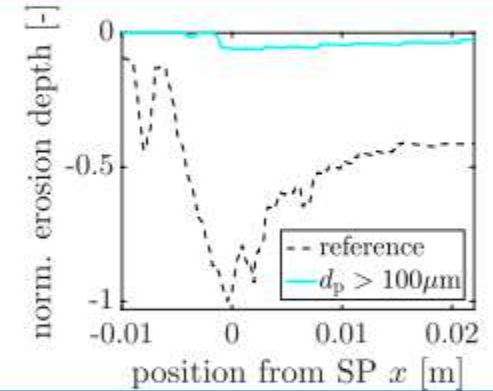
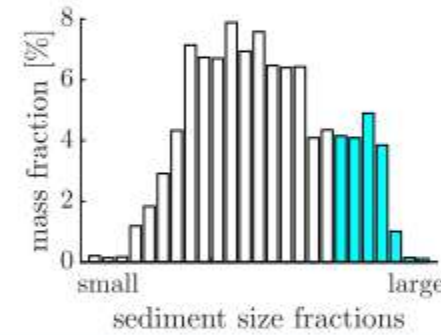
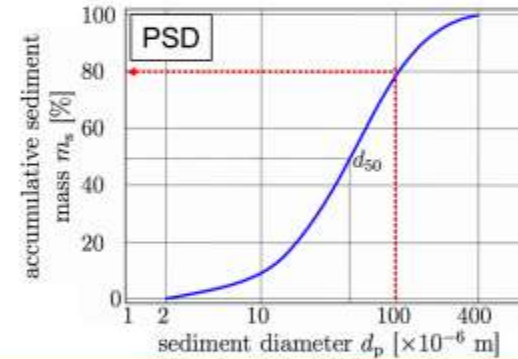
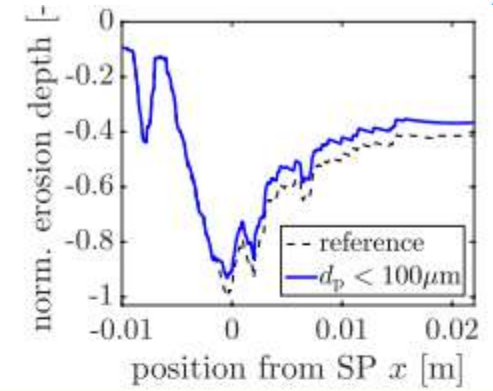
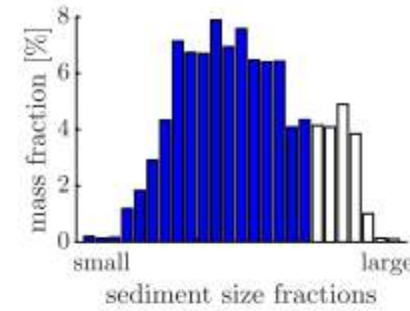
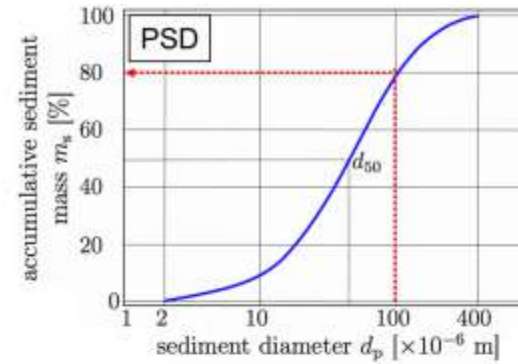
Results

- Overall good agreement with experiment
- Need to account for real sediment shape through correction factor
- Importance of turbulence description in the whole flow domain (not only in the near-wall region)



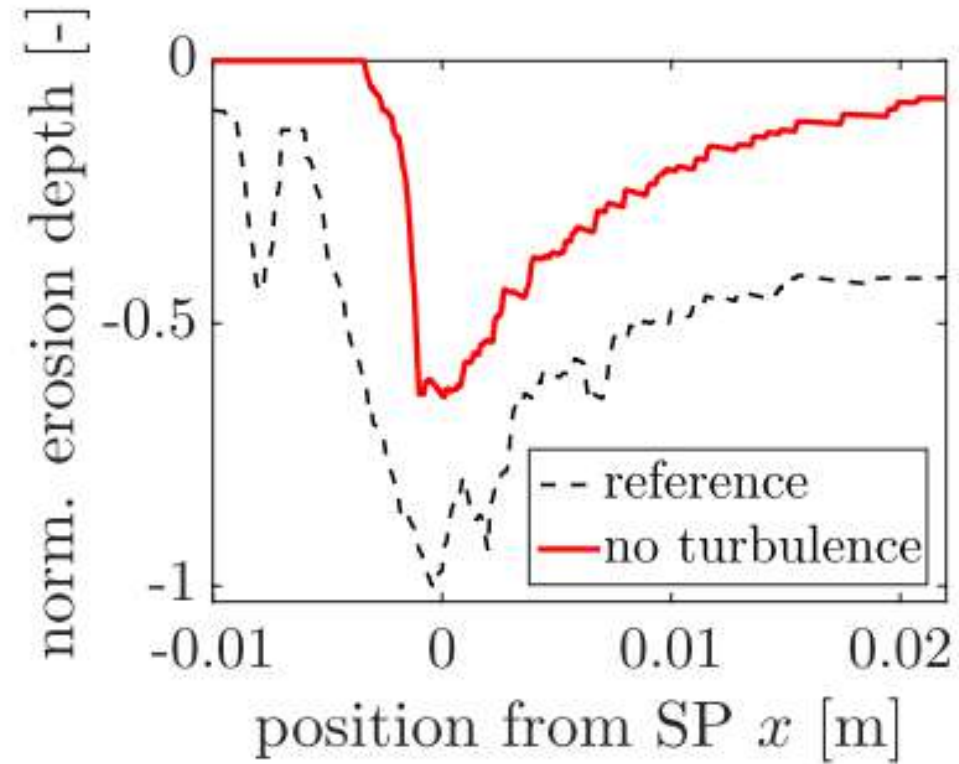
<http://predhyma.ec-lyon.fr/>

- Small sediments produce negligible erosion: **WRONG**



Learnings

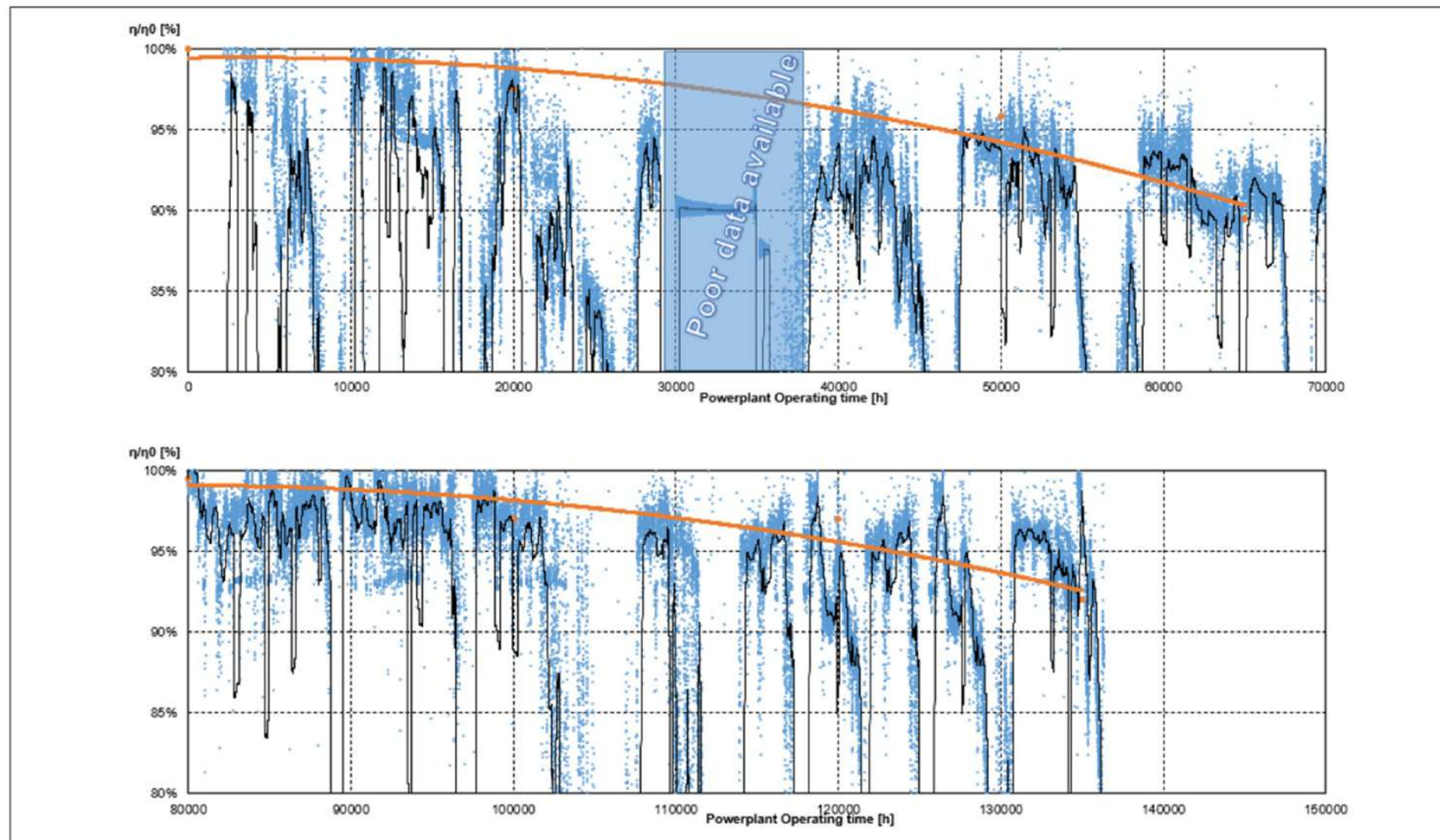
- **Small sediments produce negligible erosion: WRONG**
- **Consequently, considering only large inertia sediments, which are only slightly influenced by turbulence, the effect of turbulence can be neglected: WRONG**



FEEDBACK DA IMPIANTI ESISTENTI



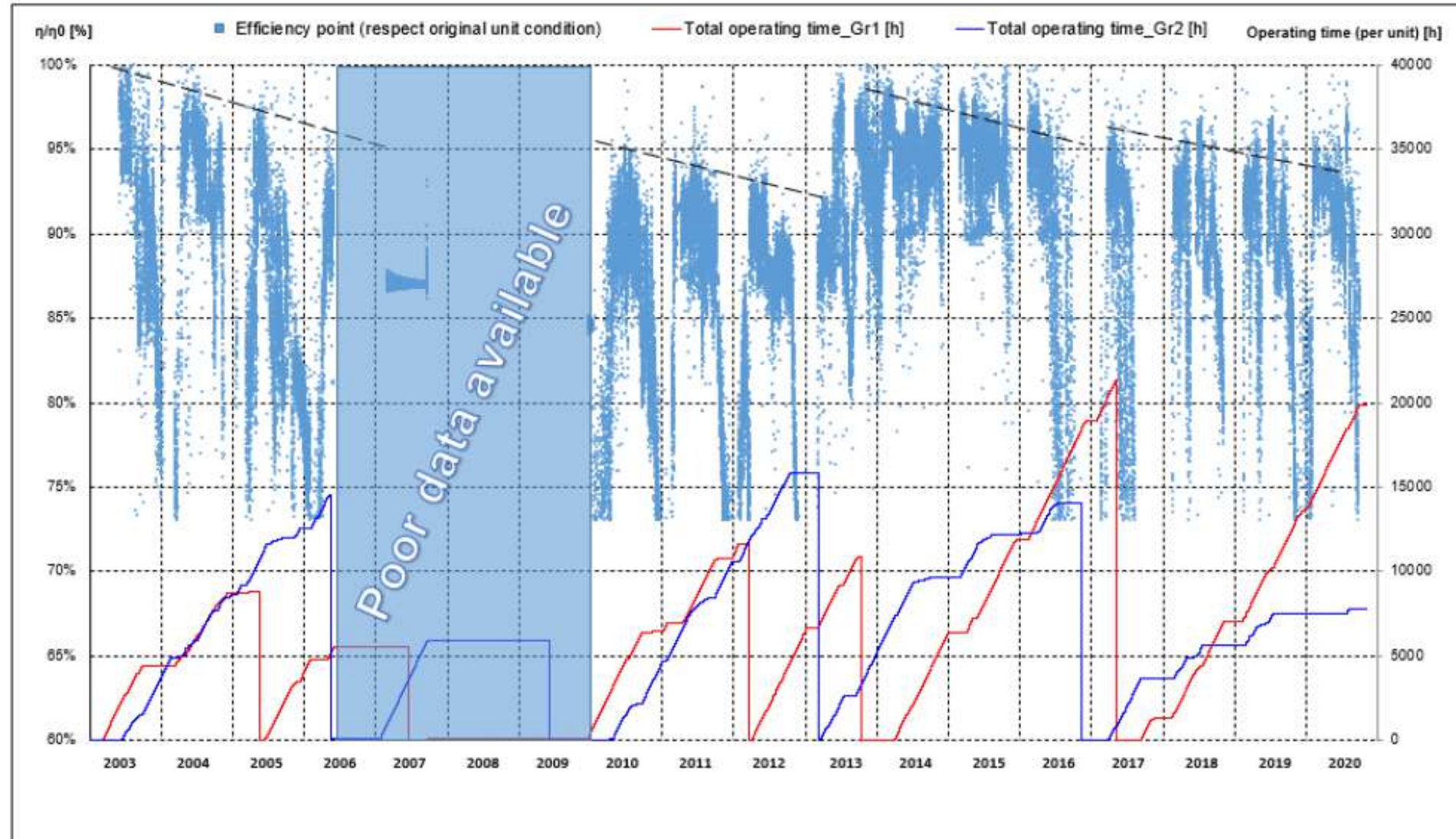
Si allega, per facilitarne la visione, quanto presentato in Figura 5-1; ovvero il decadimento delle prestazioni di impianto per i periodi 2003+2012 (sopra) 2013+2020 (sotto).



FEEDBACK DA IMPIANTI ESISTENTI



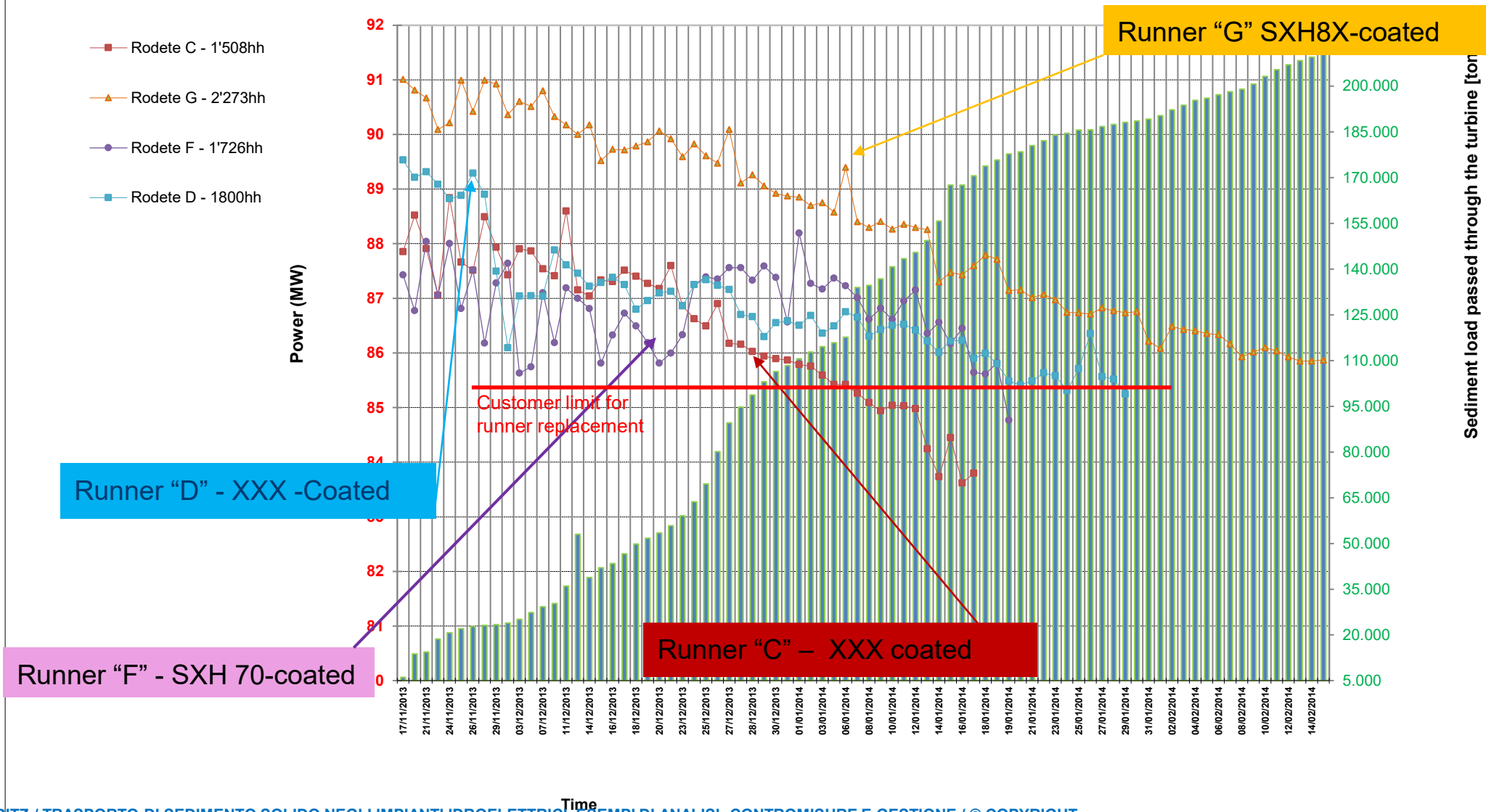
Si allega, per facilitarne la visione, quanto presentato in Figura 5-2; ovvero l'analisi del decadimento delle prestazioni e delle ore di operazione dal 2003 ad oggi.



FEEDBACK DA IMPIANTI ESISTENTI



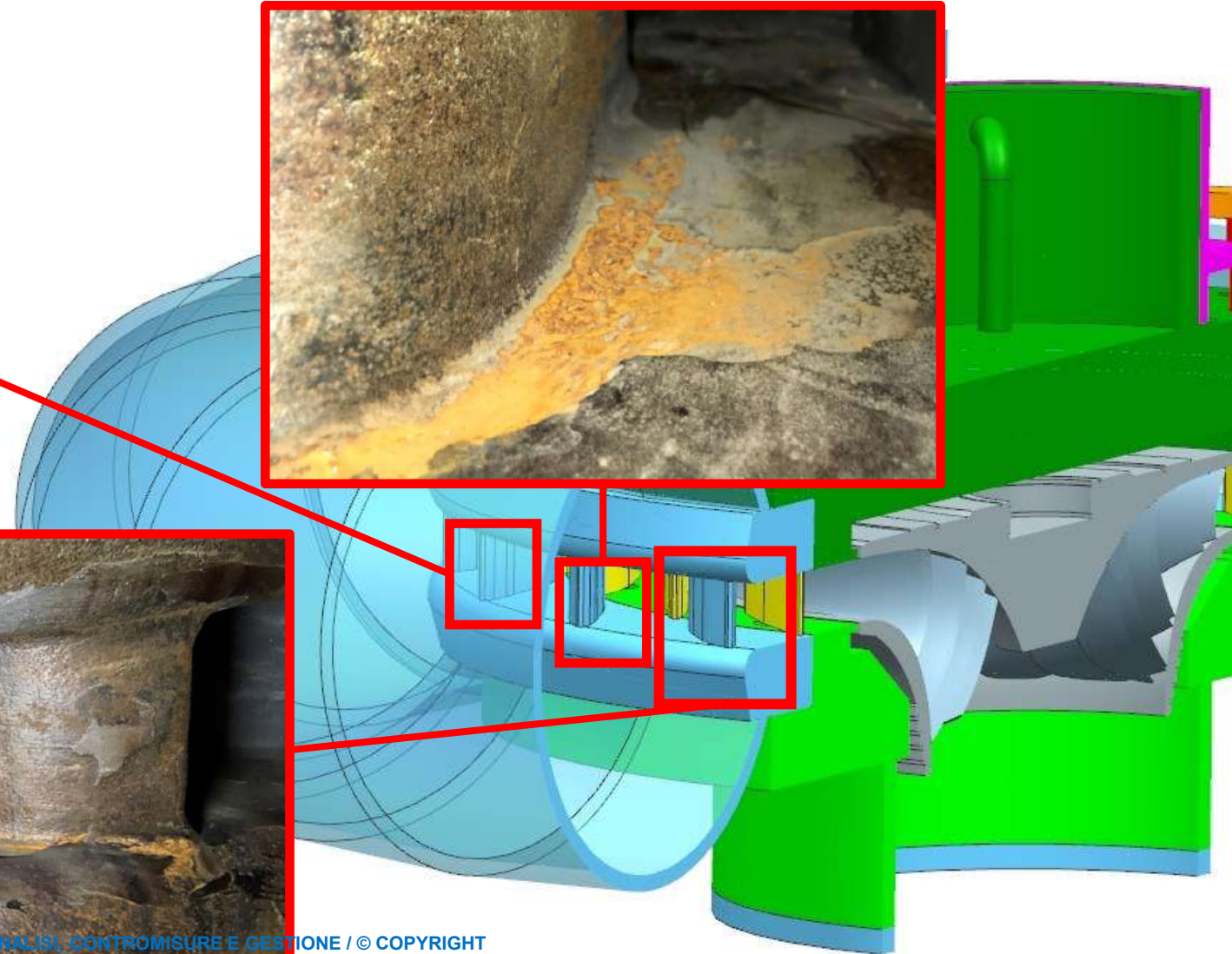
UNIT N°1 ALFALFAL-Comparison btw Runners "C-D-F-G"- Progressive Power loss
Unit at full load with H=690 mt



ESEMPIO APPLICATIVO



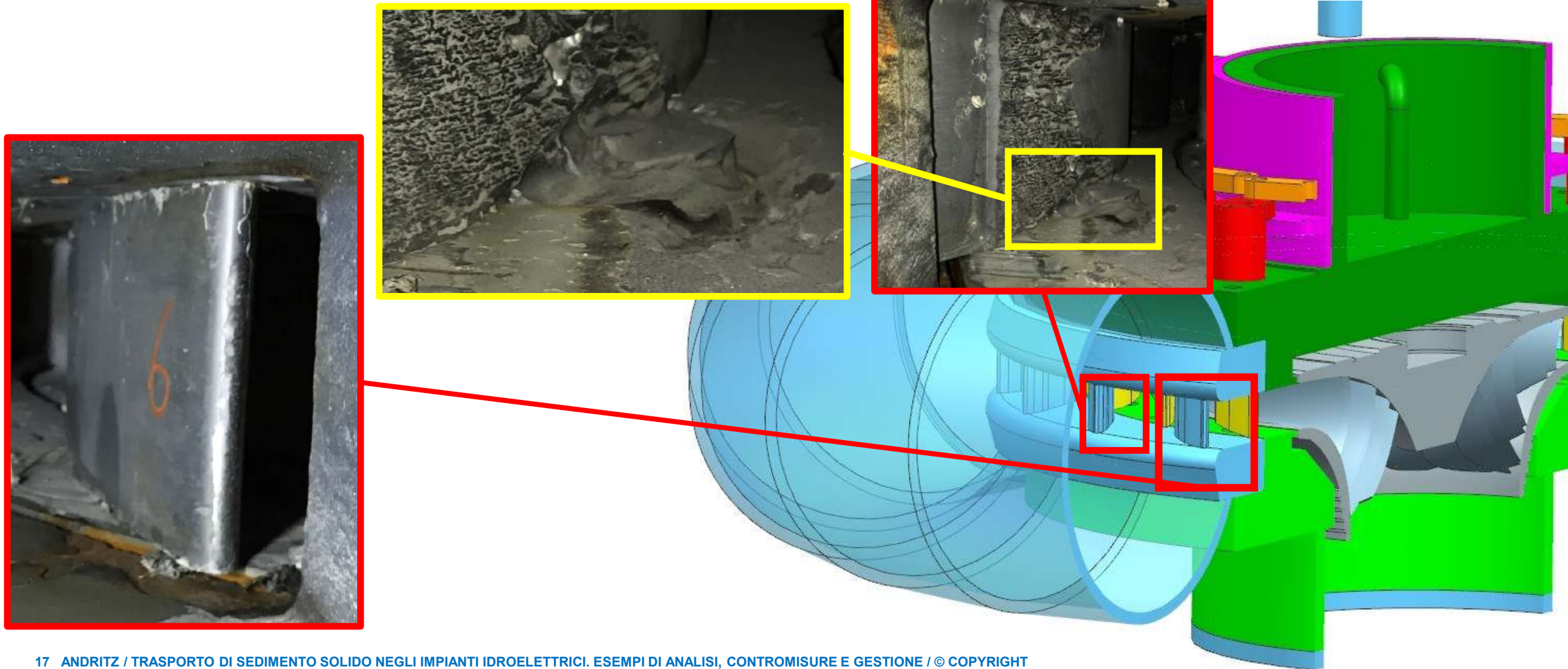
PROBLEM DESCRIPTION: Site visit – Stay Vanes



ESEMPIO APPLICATIVO



PROBLEM DESCRIPTION: Site visit – Guide Vanes



ESEMPIO APPLICATIVO



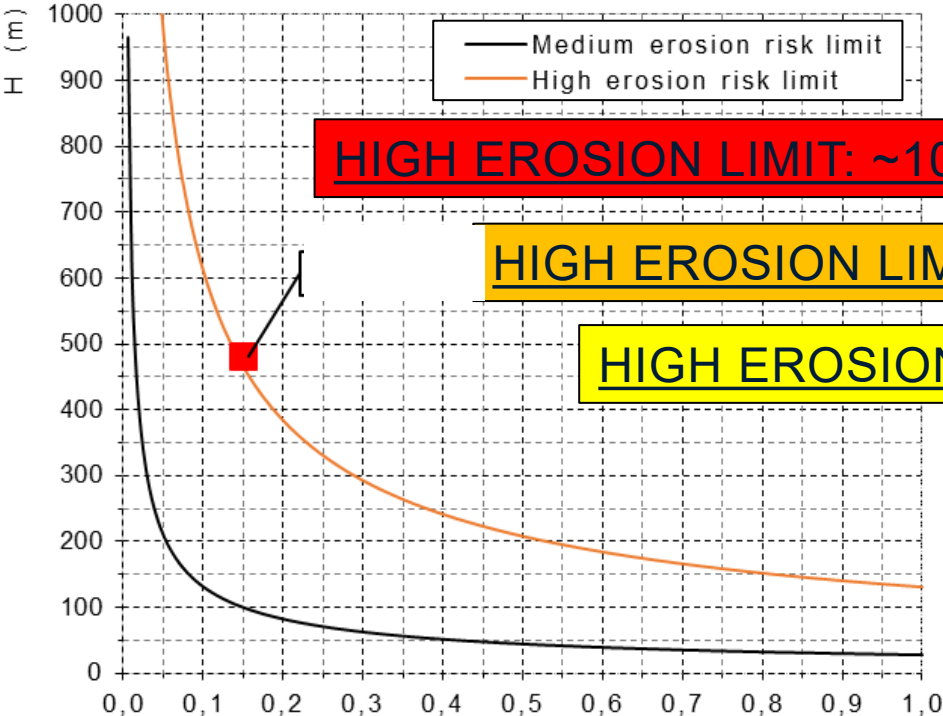
PROBLEM DESCRIPTION: Site visit – Sand Erosion

- Particle diameter: 22 μm .
- Water samples particle concentration:

0,52 kg/m^3

1,04 kg/m^3

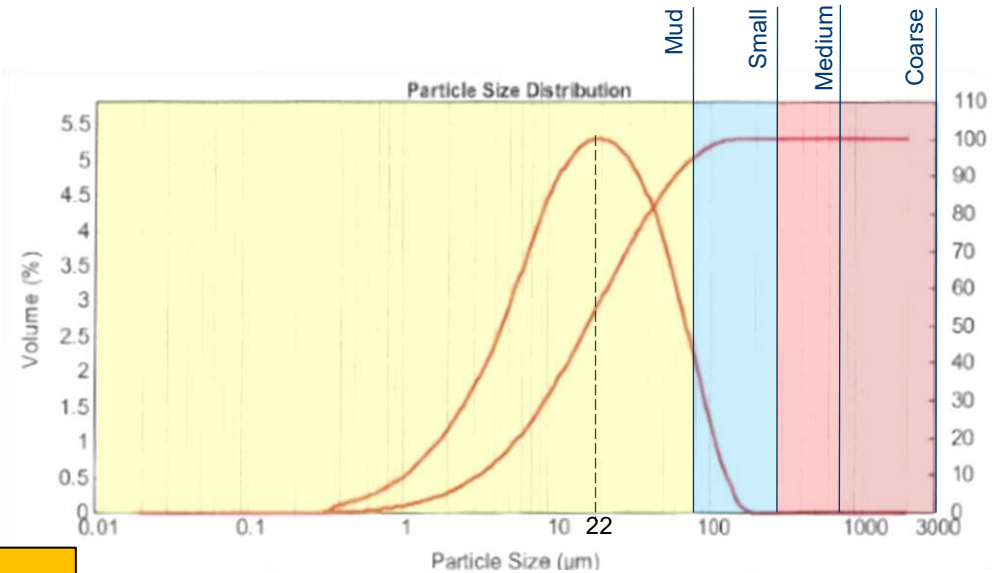
3,32 kg/m^3



HIGH EROSION LIMIT: ~100 h/year

HIGH EROSION LIMIT: ~350 h/year

HIGH EROSION LIMIT: ~700 h/year

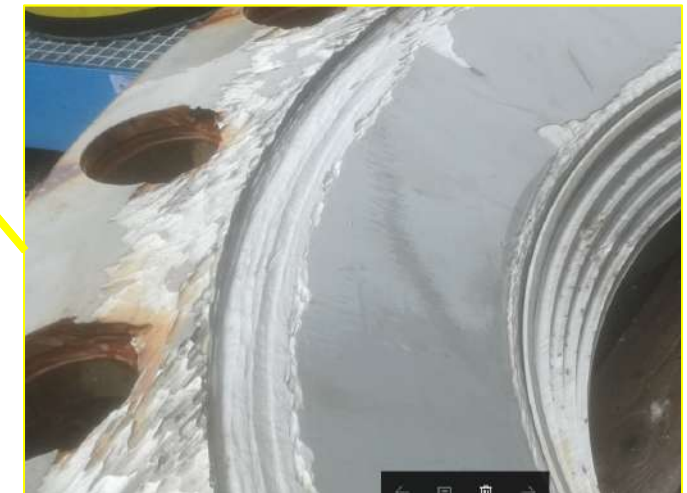
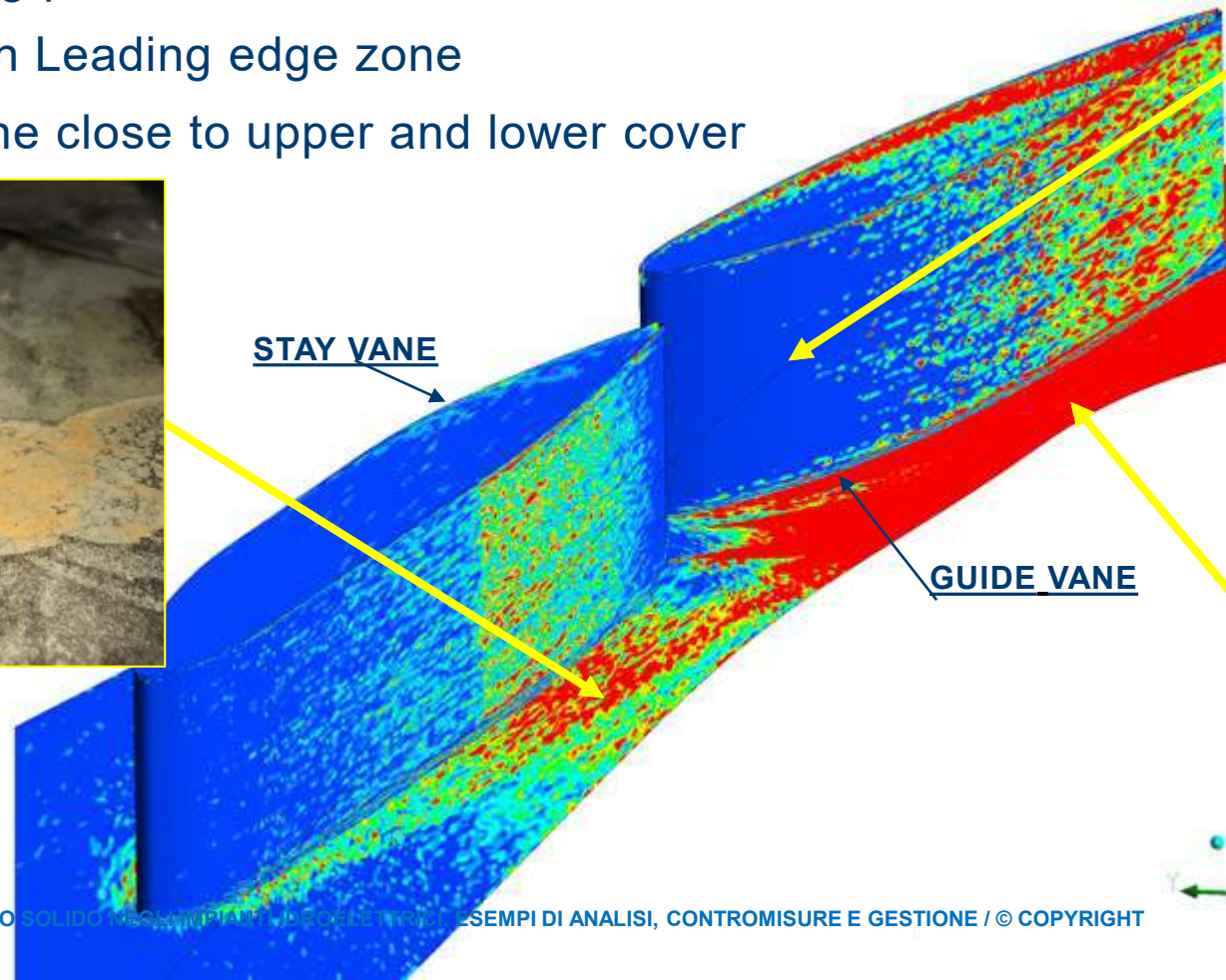


Fraction of particles with Mohs hardness	Damage Increase					
	Up to 5 (wt %)	5 to 5,4 (wt %)	5,5 to 5,9 (wt %)	6 to 6,9 (wt %)	7 to 7,9 (wt %)	8 to 8,9 (wt %)
Averaged composition	69,2	0	0	4,15	26,65	0

ESEMPIO APPLICATIVO



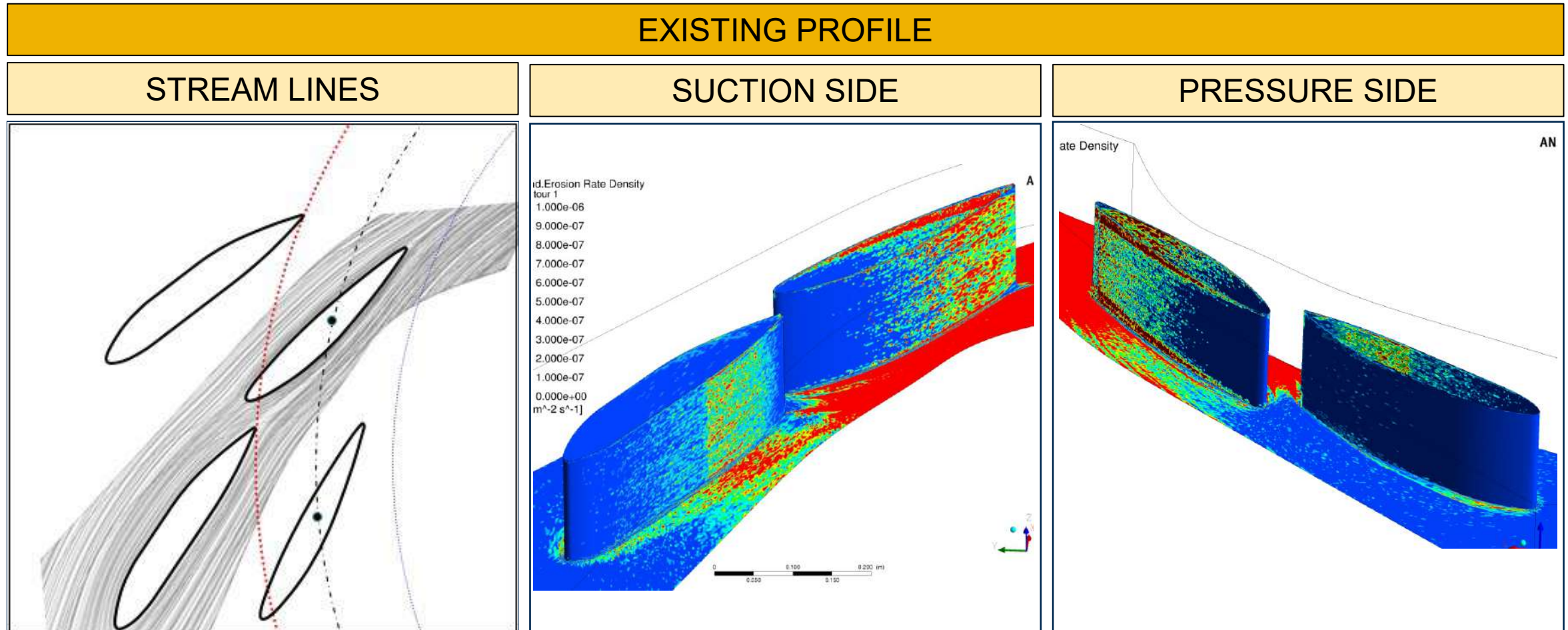
- ✓ Grooves in facing plates
- ✓ Lower damage in Leading edge zone
- ✓ High erosion zone close to upper and lower cover



ESEMPIO APPLICATIVO



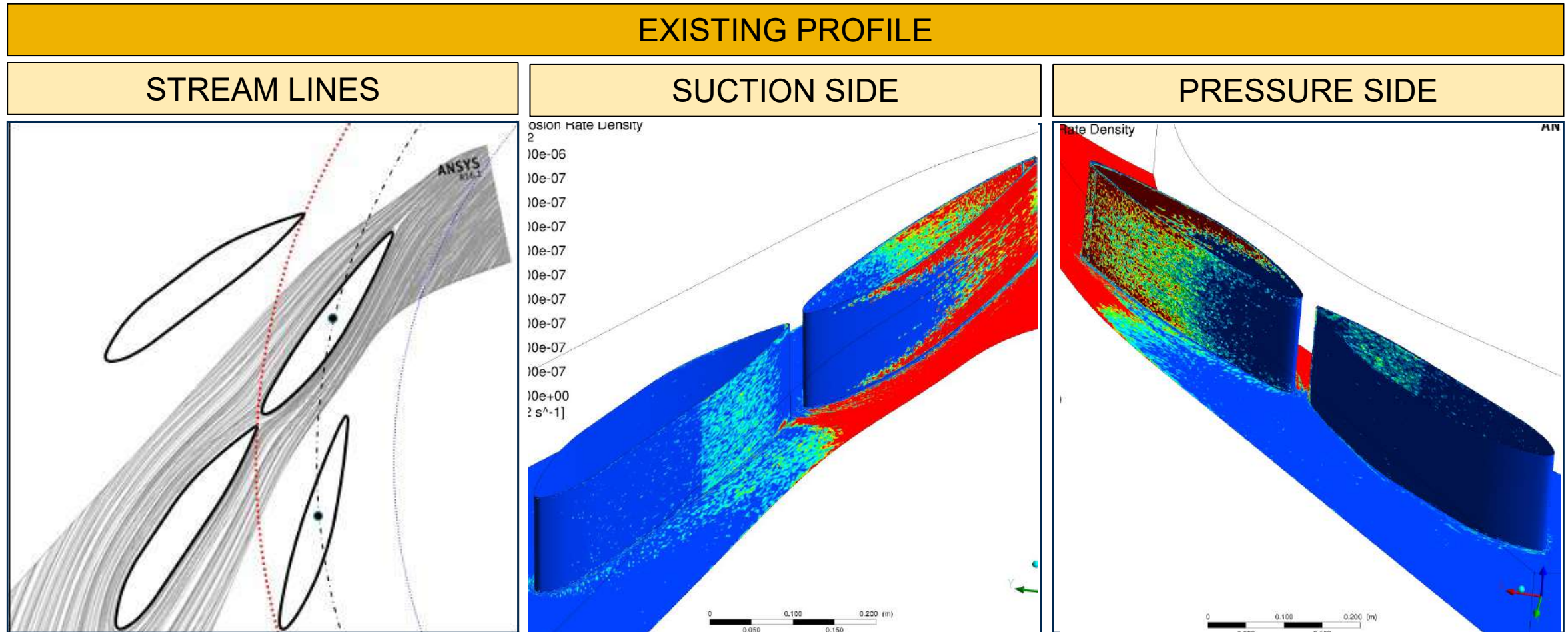
CFD SIMULATION: EROSION MAPS → RESULT FOR Q=100%



ESEMPIO APPLICATIVO



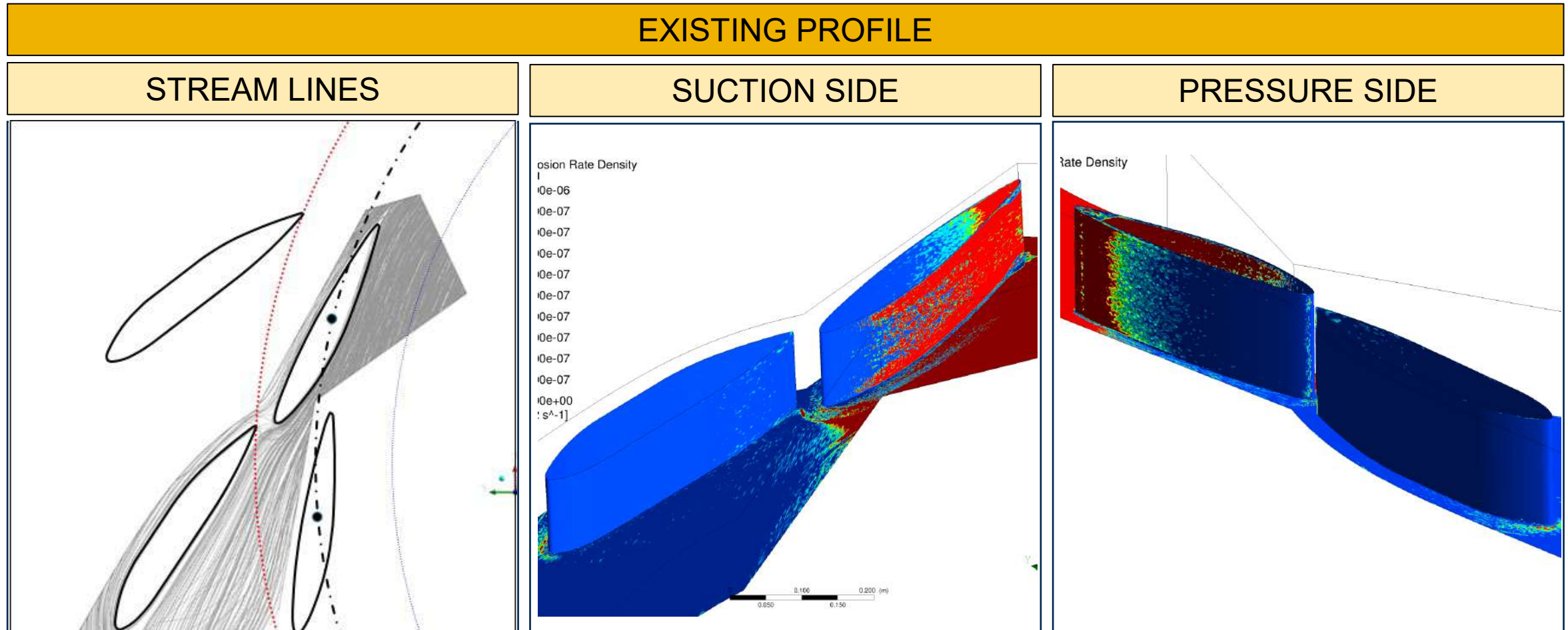
CFD SIMULATION: EROSION MAPS → RESULT FOR Q=70%



ESEMPIO APPLICATIVO



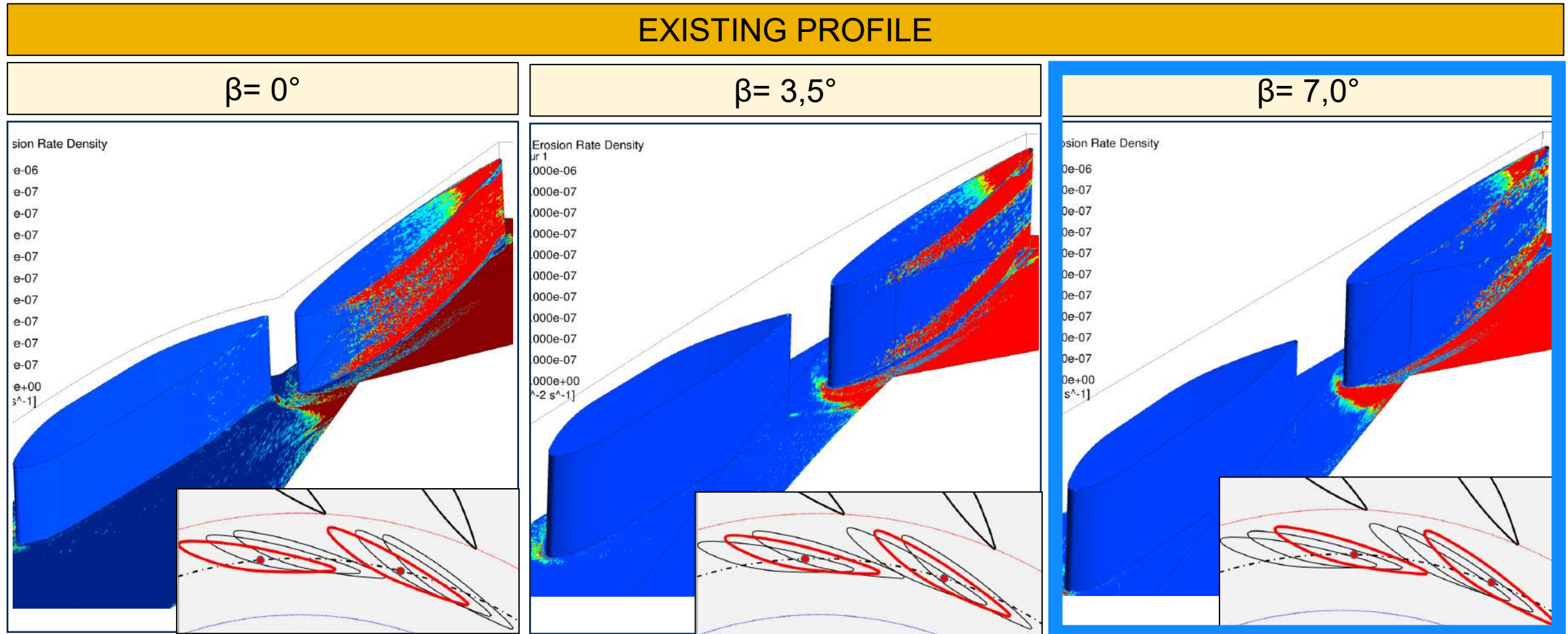
CFD SIMULATION: EROSION MAPS → RESULT FOR Q=40%



ESEMPIO APPLICATIVO



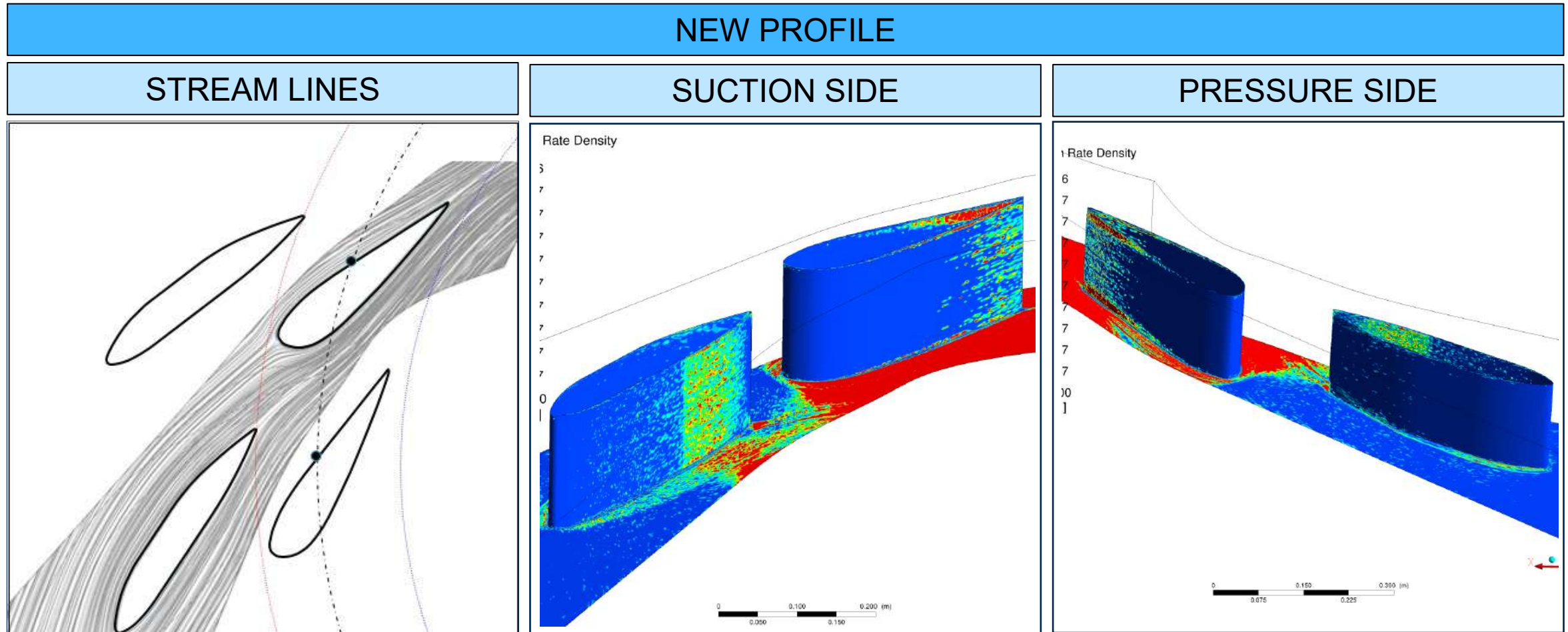
BLADES MATCHING MODIFICATION: EROSION MAPS → RESULTS FOR Q=40%



ESEMPIO APPLICATIVO



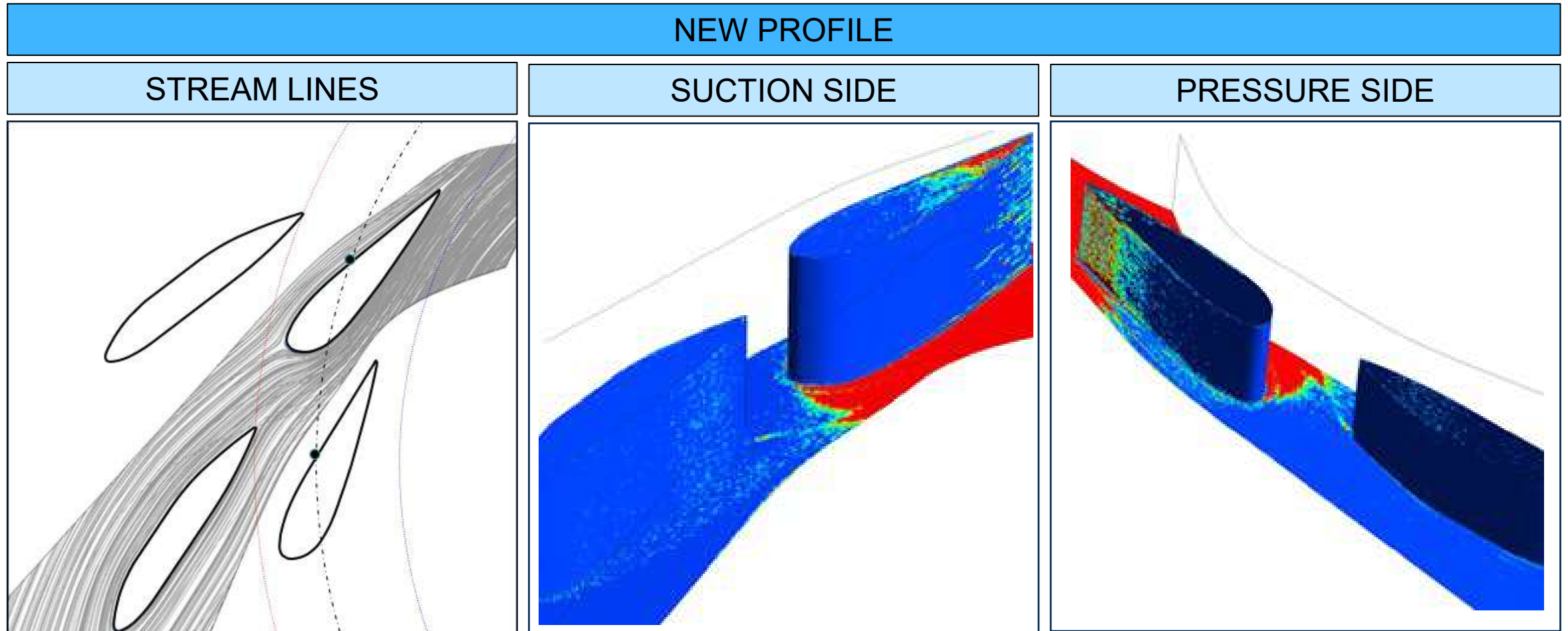
BLADES SHAPE MODIFICATION: EROSION MAPS → RESULT FOR $Q=100\%$; $\beta=7^\circ$



ESEMPIO APPLICATIVO



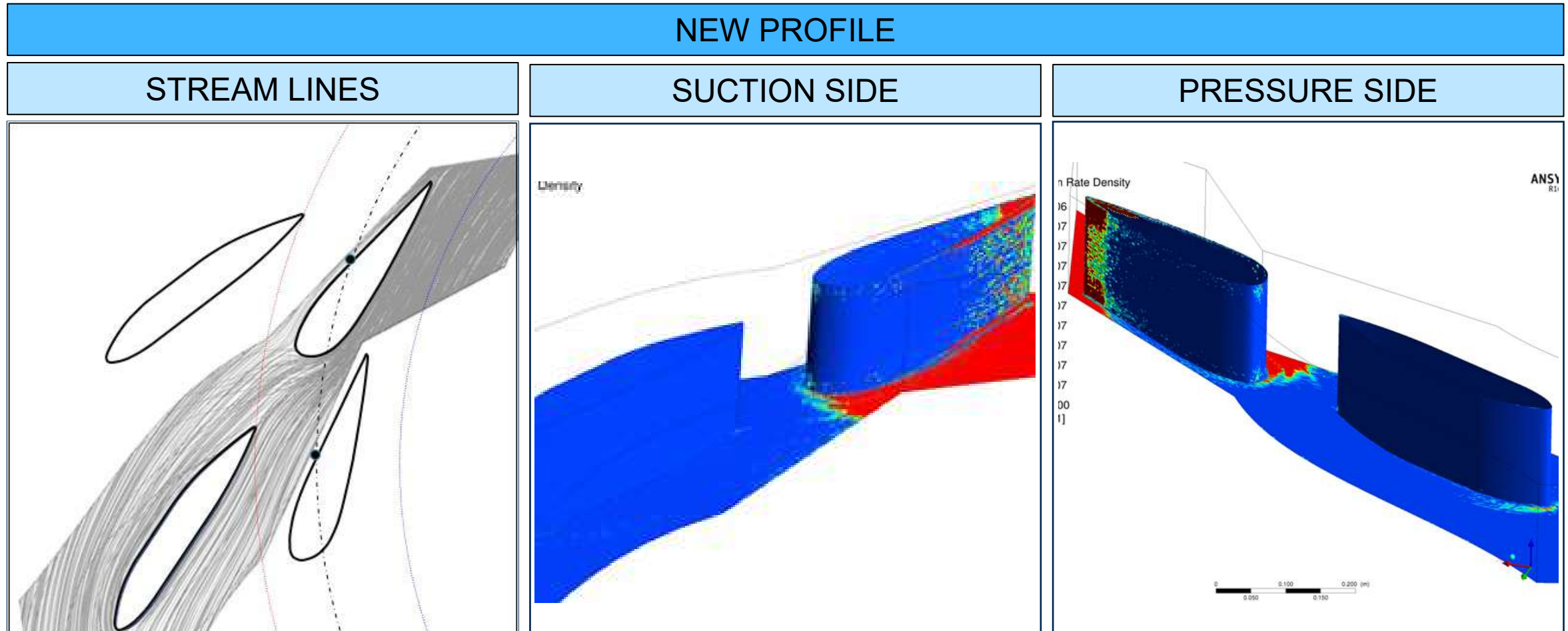
BLADES SHAPE MODIFICATION: EROSION MAPS → RESULT FOR $Q=70\%$; $\beta=7^\circ$



ESEMPIO APPLICATIVO



BLADES SHAPE MODIFICATION: EROSION MAPS → RESULT FOR $Q=40\%$; $\beta=7^\circ$

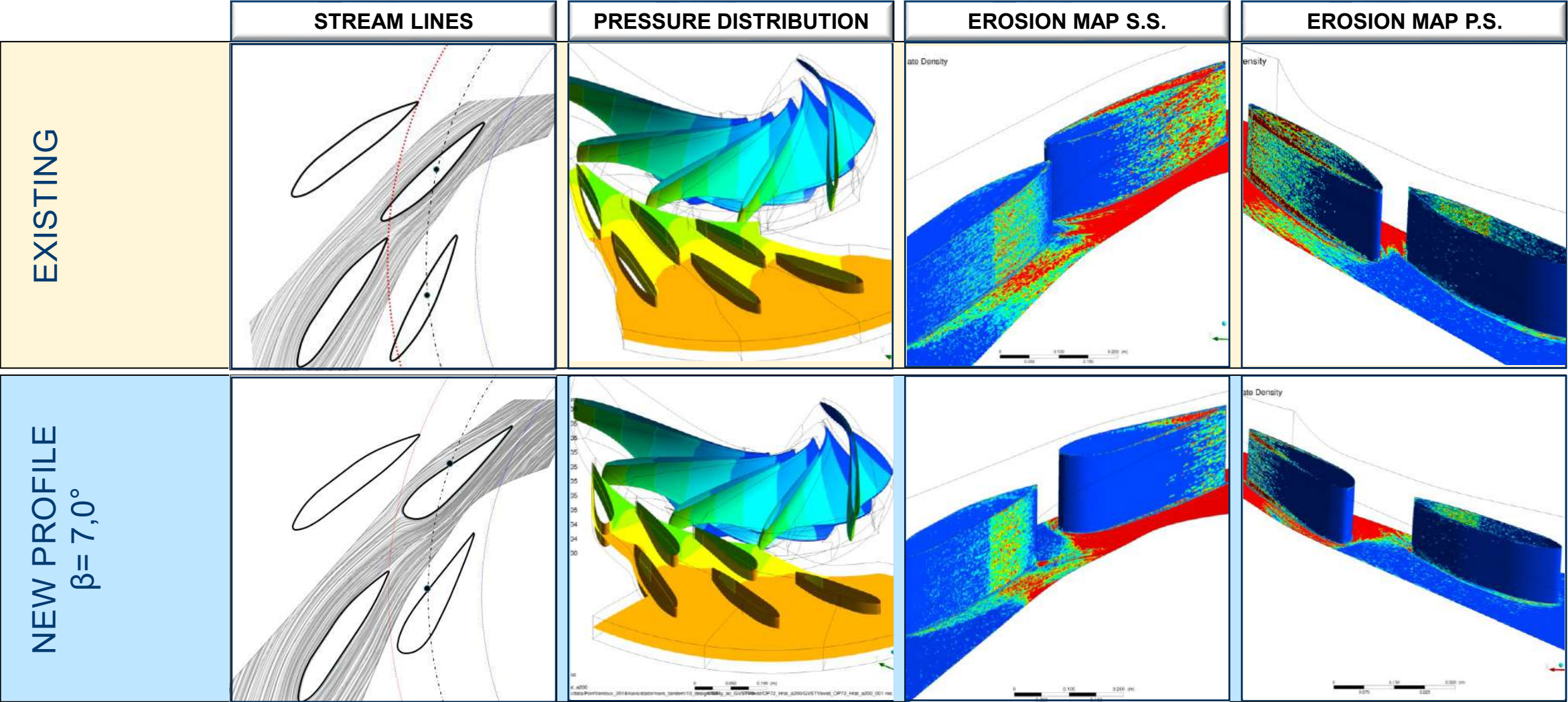


ESEMPIO APPLICATIVO



BLADES SHAPE MODIFICATION : COMPARISON FOR Q=100%

BACK

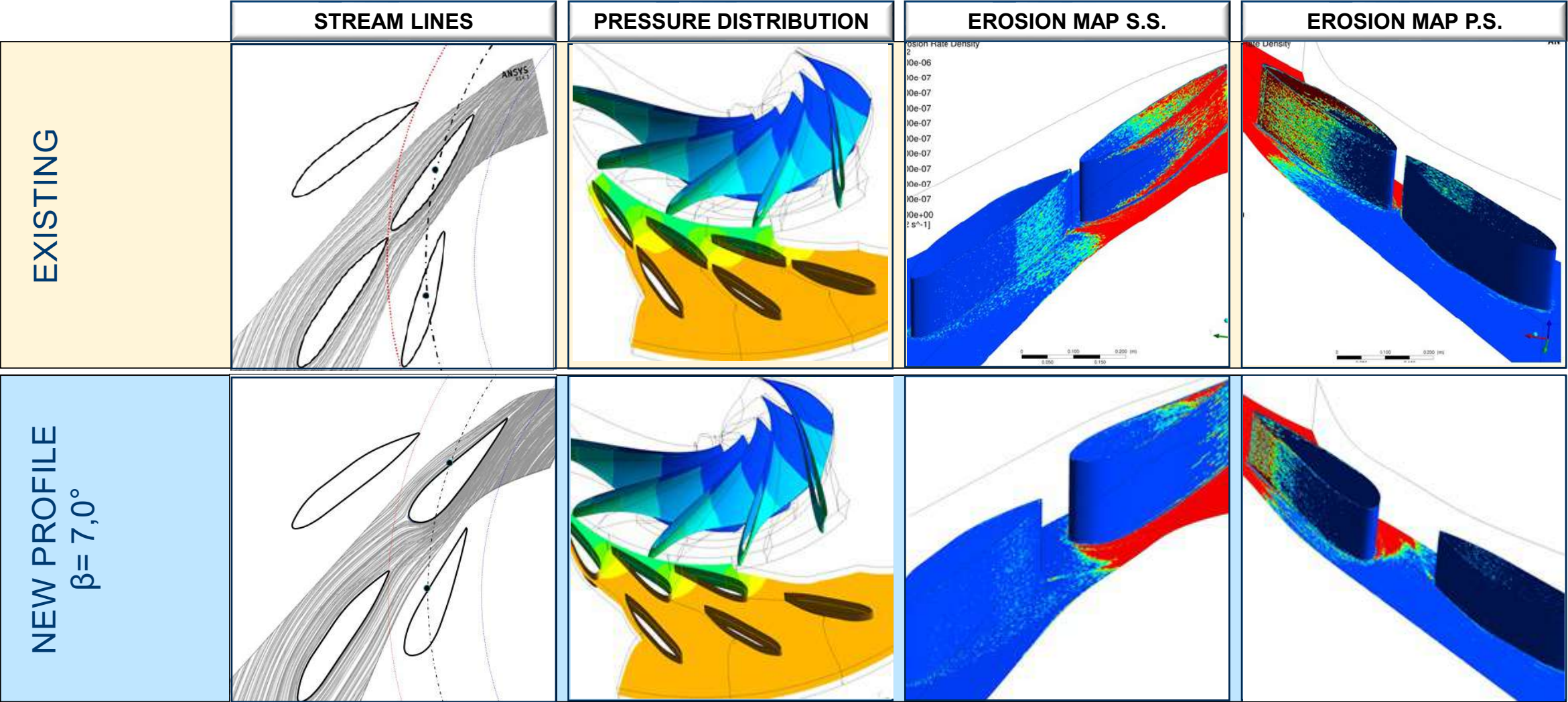


ESEMPIO APPLICATIVO



BLADES SHAPE MODIFICATION : COMPARISON FOR Q=70%

BACK

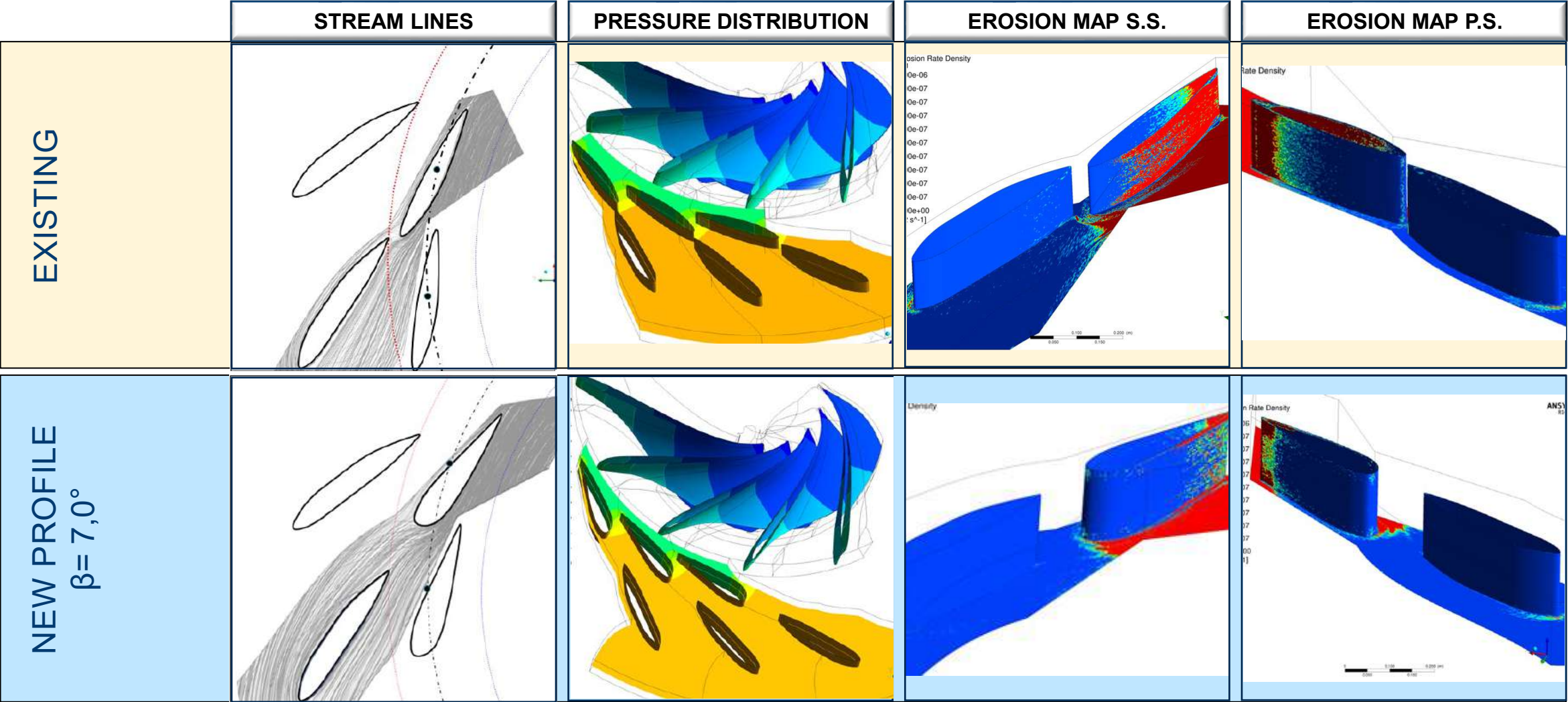


ESEMPIO APPLICATIVO



BLADES SHAPE MODIFICATION : COMPARISON FOR Q=40%

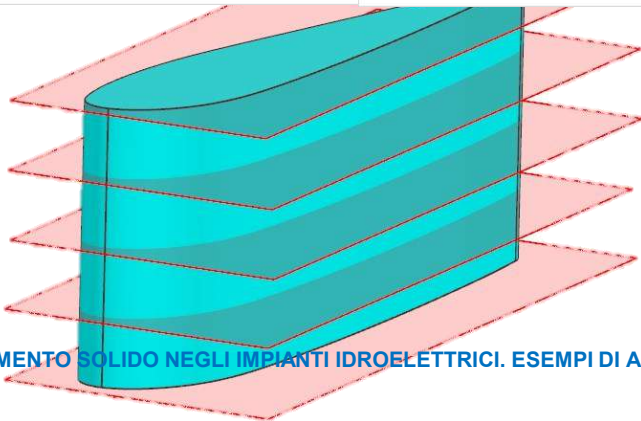
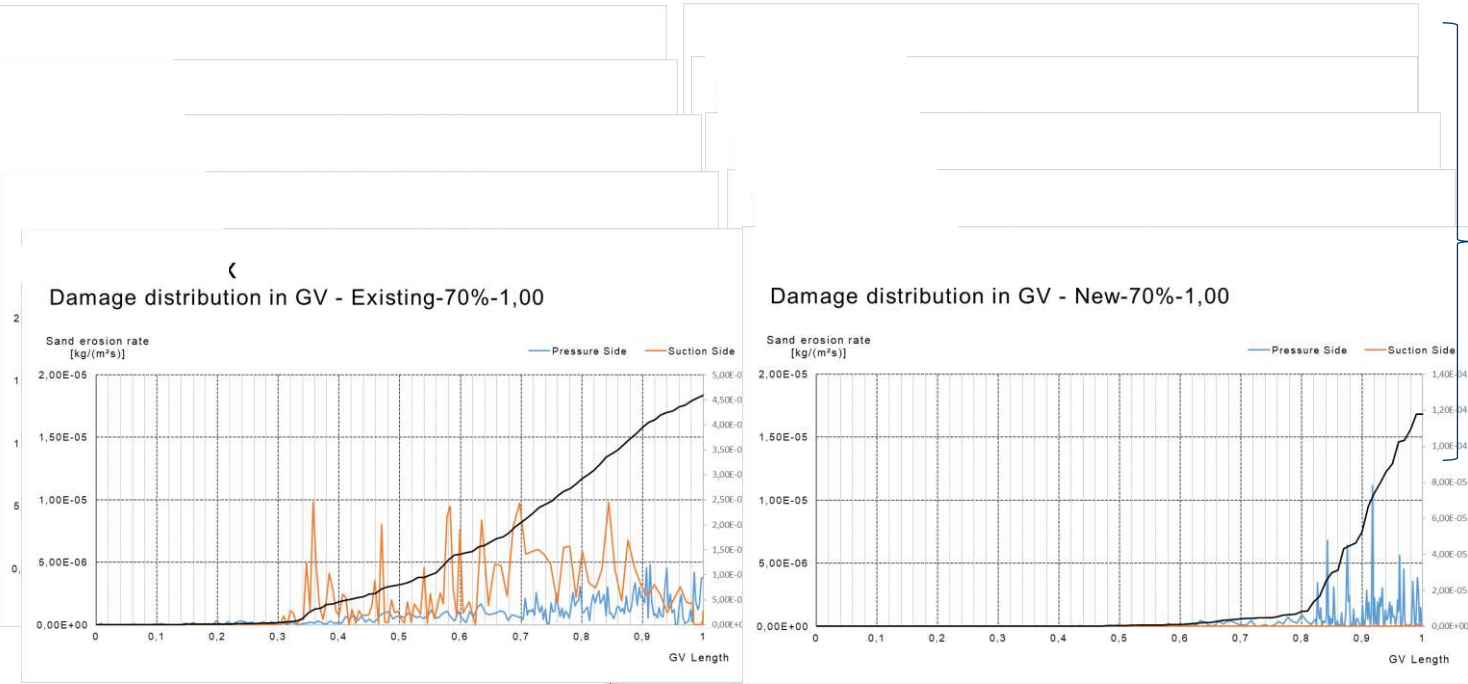
BACK



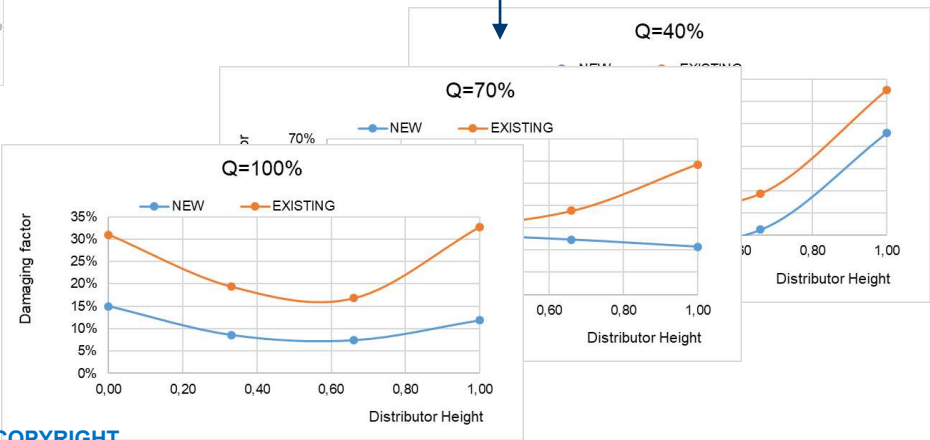
ESEMPIO APPLICATIVO



CONCLUSIONS: TBO IMPROVEMENT



EXISTING								NEW							
		PS	SS	TOT	Area	2,96E-04	100%			PS	SS	TOT	Area	1,27E-04	43%
100%	0	1,81E-04	4,64E-05	2,27E-04				100%	0	1,18E-04	6,74E-06	1,25E-04			
	0,5	8,78E-05	5,18E-05	1,40E-04	0,00	9,16E-05	31%		0,5	4,93E-05	3,18E-06	5,24E-05	0,00	4,44E-05	15%
	1	4,90E-05	4,13E-05	9,02E-05	0,33	5,75E-05	19%		1	4,70E-05	2,33E-06	4,93E-05	0,33	2,54E-05	9%
	1,5	6,50E-05	4,37E-05	1,09E-04	0,66	4,97E-05	17%		1,5	2,64E-05	1,19E-05	3,84E-05	0,66	2,19E-05	7%
	2	2,36E-04	4,23E-05	2,78E-04	1,00	9,68E-05	33%		2	9,96E-05	2,22E-06	1,02E-04	1,00	3,50E-05	12%
70%	0	1,82E-04	2,24E-04	4,06E-04				70%	0	1,18E-04	2,70E-06	1,21E-04			
	0,5	1,41E-04	3,90E-05	1,80E-04	0,00	1,47E-04	50%		0,5	1,53E-04	3,85E-06	1,57E-04	0,00	6,94E-05	23%
	1	1,64E-04	4,92E-05	2,14E-04	0,33	9,85E-05	33%		1	1,52E-04	4,05E-06	1,56E-04	0,33	7,83E-05	26%
	1,5	1,41E-04	9,05E-05	2,31E-04	0,66	1,11E-04	38%		1,5	1,34E-04	2,06E-06	1,36E-04	0,66	7,30E-05	25%
	2	1,93E-04	2,66E-04	4,59E-04	1,00	1,73E-04	58%		2	1,17E-04	4,09E-07	1,18E-04	1,00	6,34E-05	21%
40%	0	2,78E-04	5,53E-04	8,31E-04				40%	0	4,88E-05	1,02E-03	1,07E-03			
	0,5	6,71E-05	2,77E-04	3,44E-04	0,00	2,94E-04	99%		0,5	1,54E-05	1,91E-05	3,44E-05	0,00	2,75E-04	93%
	1	7,47E-05	5,60E-06	8,03E-05	0,33	1,06E-04	36%		1	1,17E-05	1,28E-05	2,45E-05	0,33	1,47E-05	5%
	1,5	8,26E-05	2,79E-04	3,62E-04	0,66	1,10E-04	37%		1,5	1,13E-05	2,38E-05	3,51E-05	0,66	1,49E-05	5%
	2	2,66E-04	9,12E-04	1,18E-03	1,00	3,85E-04	130%		2	5,72E-05	9,92E-04	1,05E-03	1,00	2,71E-04	92%



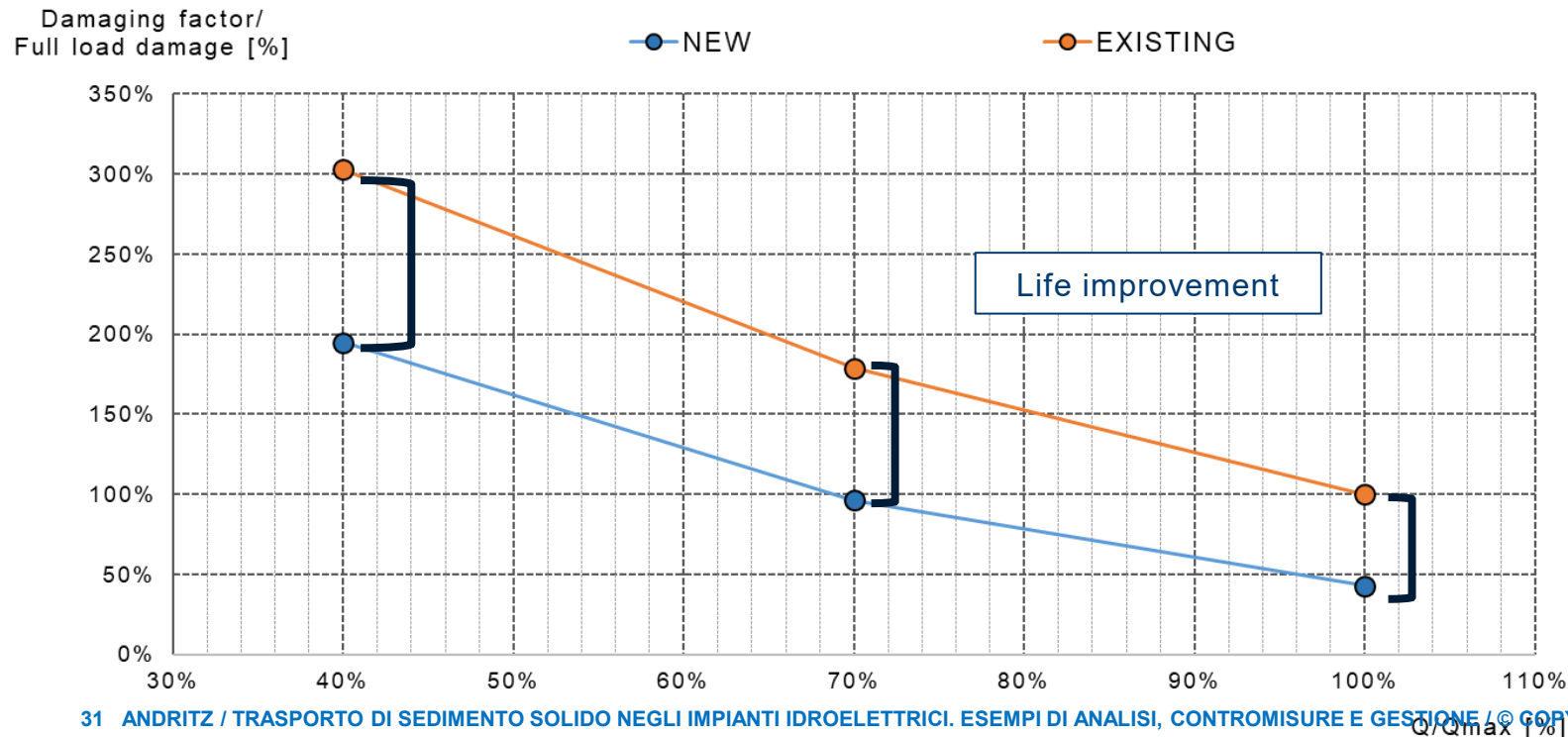
ESEMPIO APPLICATIVO



CONCLUSIONS: TBO IMPROVEMENT

- ✓ All parameters are in % of Full Load damage at existing condition
- ✓ Operation Factor dependent

TBO IMPROVEMENT:
47%



Q/Qmax [%]	Operation Factor	Life improvement [%]
100%	0,30	42,9%
70%	0,50	53,7%
40%	0,20	64,3%

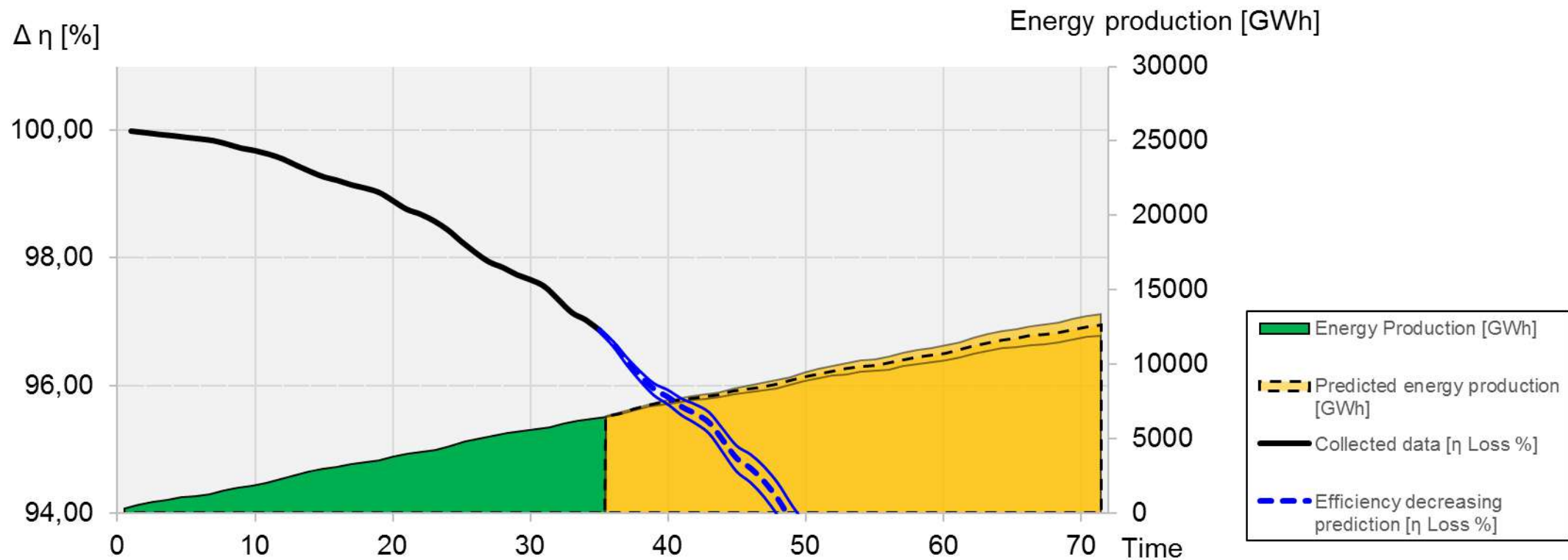
~2500 h/Year	TBO	TBO NEW
Tot [h]	11000	16200
TOT [year]	4,40	6,48

SPARE MANAGEMENT



Our digital O&M solution to optimize your business

PERFORMANCES PREDICTION



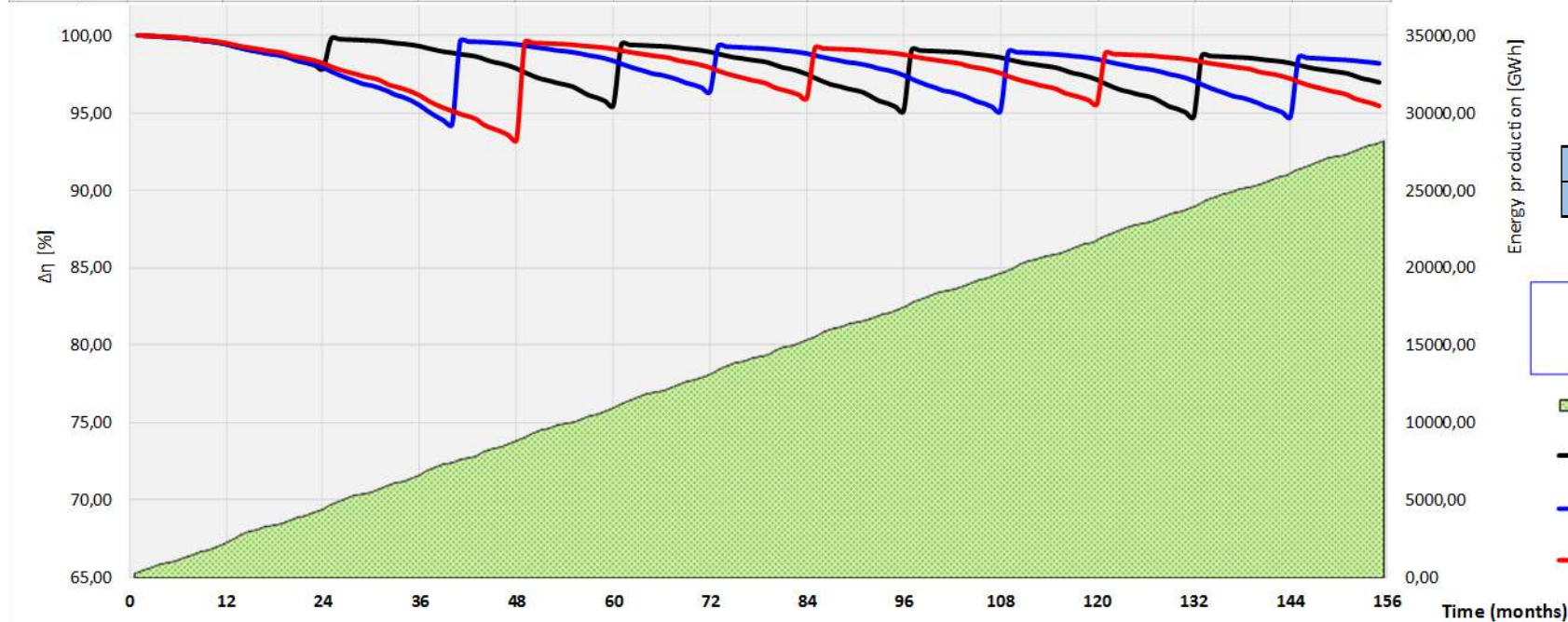
SPARE MANAGEMENT



Our digital O&M solution to optimize your business

SIMULATION OF SEVERAL DIFFERENT SCENARIOS

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Unit1	-	-	Major	-	-	Major	-	-	Major	-	-	Major	-
Unit2	-	-	-	Major	-	-	Major	-	-	Major	-	-	Major
Unit3	-	-	-	-	Major	-	-	Major	-	-	Major	-	-
Coating	No	No	No	No	No	No	No	No	No	No	No	No	No



Energy price [USD/MWh]
52

Days for rehab	
Mayor	Minor
31	22

	Rehab Costs [k USD]	
	Mayor	Minor
Coating YES	3600	~0
Coating NO	1800	600

Simulation 7

- Energy production [GWh]
- $\Delta\eta_{U1}$ [%]
- $\Delta\eta_{U2}$ [%]
- $\Delta\eta_{U3}$ [%]

SPARE MANAGEMENT



Our digital O&M solution to optimize your business

MAXIMIZE POWERPLANT PRODUCTIVITY



Our digital O&M solution to optimize your business

MAXIMIZE POWERPLANT PRODUCTIVITY

FINAL STEP OPTIMIZATION IS MADE OF:

ANDRITZ EXPERIENCE

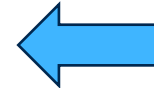


CLIENT DEPENDING VARIABLES

- DATA COLLECTION
- PERFORMANCES PREDICION
- REHAB COSTS PREDICTION
- DOWNTIME COSTS PREDICTION
- MAXIMIZE PRODUCTIVITY
- LOAD DISPACING
- COATING



FINAL OPTIMIZATION
“Taylor made approach”



- FINANCIAL SITUATION
- HPP SAFETY
- ROLE IN GRID
- PLANT FACTOR
- PLANT AVAILABILITY
- VARIABLE ENERY PRICE
- OTHER...

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