TOP CSP

Funded by the European Union

Towards, Competitive, Reliable, Safe and Sustainable Concentrated Solar Power (CSP) Plants

Midterm meeting REA, 18-19 April 2024

DC 9: Coupled optimization of solar field and receiver/cavity geometry and thermal/hydraulic design

Tom Todtenhaupt

UNIVERSIDAD DE SEVILLA

VIRTUALMECH
KEEPING YOUR WORLD IN MOTION

T O P C S P

VIRTUALMECH
KEEPING YOUR WORLD IN MOTION

Funded by the European Union

TOP C S P

1	Introduction
2	Receiver Optimization
3	Reduced Order Model
4	Future Work

Funded by the European Union

HORIZON MSCA Doctoral Network, Project number 101072537

Introduction

Education:

- Bachelor Mechanical Engineering, Clausthal University of Technology
- Master Mechanical Engineering, Clausthal University of Technology

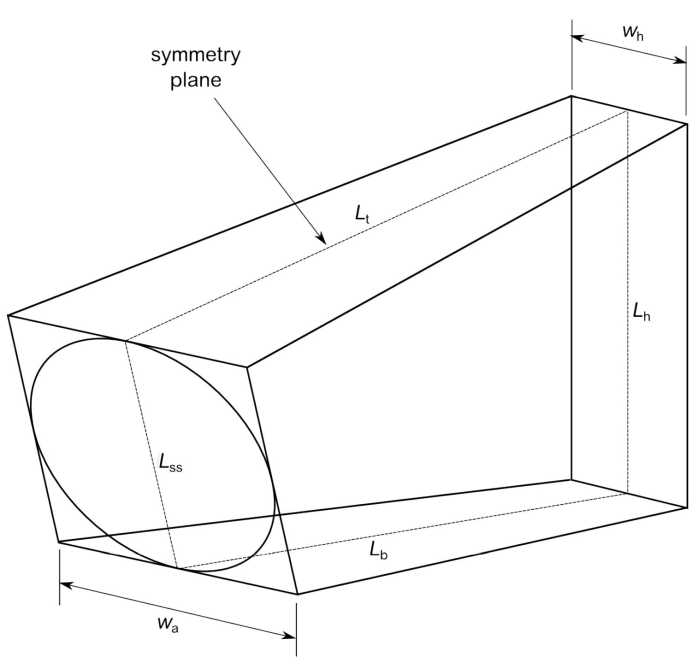
Experience:

- Research assistant, Institute of Tribology and Energy Conversion Machinery, Clausthal-Zellerfeld
- Intern Audi Sport, Neuburg a.d. Donau
- PhD fellow TOPCSP, Sevilla

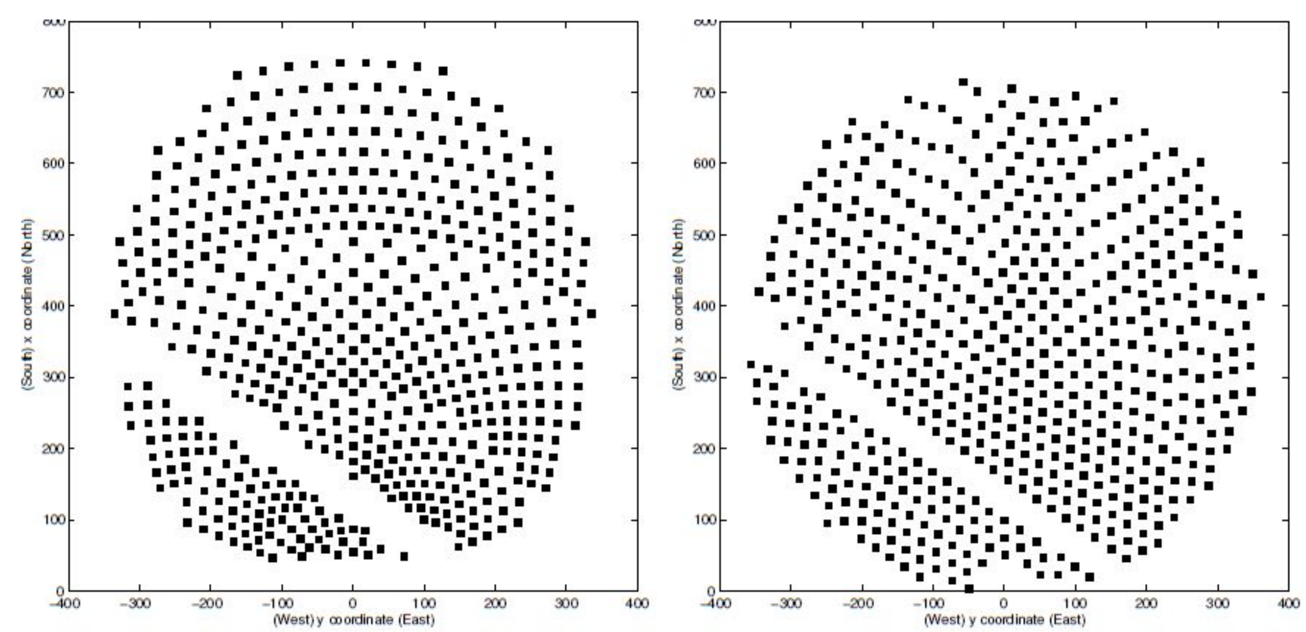
Funded by the European Union

Introduction

- Central receiver/cavity geometry optimization
- Solar field optimization
- So far, these optimizations were done independently
- Goal: coupling these optimizations



[1]



[2]

Funded by the European Union
HORIZON MSCA Doctoral Network, Project number 101072537

1 Introduction

2 Receiver Optimization

3 Reduced Order Model

4 Future Work

Funded by the European Union

HORIZON MSCA Doctoral Network, Project number 101072537

Receiver Optimization

Design parameters: $\chi = (L_1 \;\; L_2 \;\; L_4 \;\; \theta_1 \;\; \theta_2 \;\; w_1 \;\; w_2)$

Objective function: $Q_{ls} = Q_{conv} + Q_{rad} + Q_{opt}$

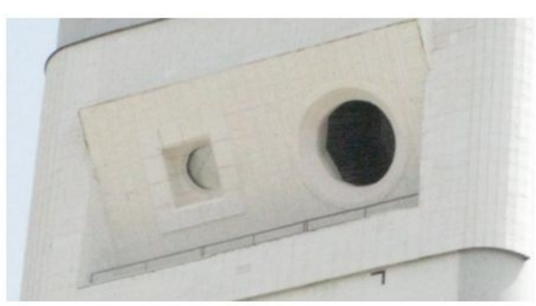
$$Q_{conv} = h \cdot A \cdot \Delta T \quad ; \quad h = \frac{Nu \cdot k}{L}$$

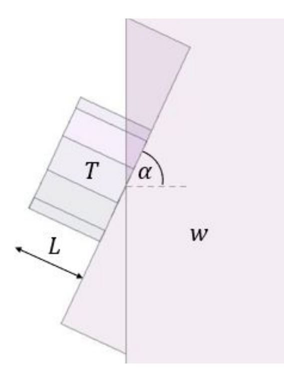
$$Nu = 0{,}122 \cdot Ra^{0{,}31} \cdot \left(\frac{T_w}{T_a}\right)^{0{,}066} \cdot (1 + \cos(\theta)\,)^{0{,}38}$$

Optimization Problem:

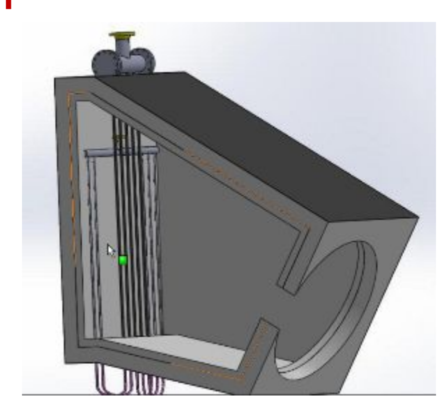
$$minimize \quad Q_{ls} = Q_{ls}(\chi, T_w, p)$$
$$subject\ to \quad \chi_{lb} \le \chi \le \chi_{ub} \;\; ; \;\; g(\chi) \le G \;\; ; \;\; h(\chi) = H$$

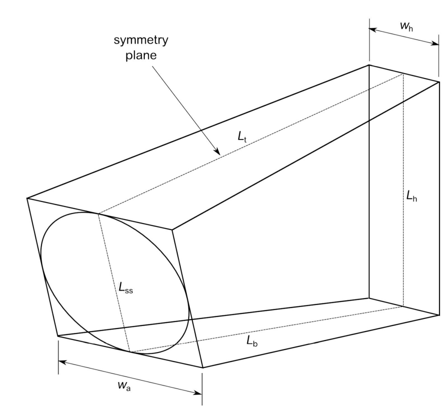
Replace Nusselt-number-correlation with coupled Reduced-Order-Models for receiver design optimization





[3]





[1]

Funded by the European Union

HORIZON MSCA Doctoral Network, Project number 101072537

Reduced Order Model

- Proper Orthogonal Decomposition / Singular Value Decomposition (SVD)

$$x_i \in \mathbb{R}^n \qquad n >> m$$

$$X = \begin{bmatrix} | & | & & | \\ x_1 & x_2 & \dots & x_m \\ | & | & & | \end{bmatrix} = U\Sigma V^T = \begin{bmatrix} | & | & & | \\ u_1 & u_2 & \dots & u_n \\ | & | & & | \end{bmatrix} \begin{bmatrix} \sigma_1 & & & \\ & \sigma_2 & & \\ & & \ddots & \\ & & & \sigma_m \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} - & v_1^T & - \\ - & v_2^T & - \\ & \vdots & \\ - & v_m^T & - \end{bmatrix}$$

$$= \sigma_1 u_1 v_1^T + \sigma_2 u_2 v_2^T + \cdots + \sigma_m u_m v_m^T + 0$$

[4]

Reduced Order Model

- Proper Orthogonal Decomposition / Singular Value Decomposition (SVD)

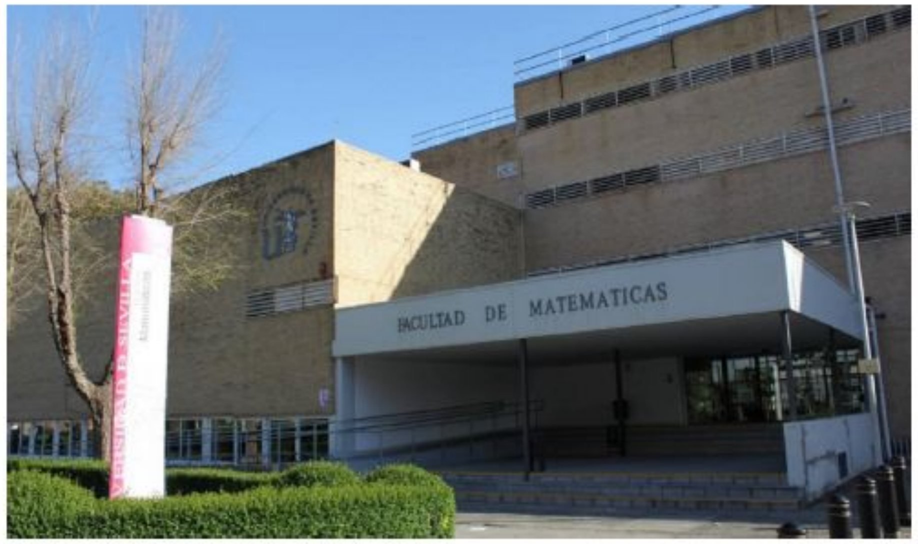
$$x_i \in \mathbb{R}^n \qquad n >> m$$

$$X = \begin{bmatrix} | & | & & | \\ x_1 & x_2 & \dots & x_m \\ | & | & & | \end{bmatrix} = U\Sigma V^T = \begin{bmatrix} | & | & & | \\ u_1 & u_2 & \dots & u_n \\ | & | & & | \end{bmatrix} \begin{bmatrix} \sigma_1 & & & \\ & \sigma_2 & & \\ & & \ddots & \\ & & & \sigma_m \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} - & v_1^T & - \\ - & v_2^T & - \\ & \vdots & \\ - & v_m^T & - \end{bmatrix}$$

$$\sigma_1 u_1 v_1^T + \sigma_2 u_2 v_2^T + \cdots + \cancel{\sigma_m u_m v_m^T} + 0 = \tilde{U}\tilde{\Sigma}\tilde{V}^T$$ [4]

Truncation at rank r

Reduced Order Model



(a) Original image

(b) SVD Approximation of rank 5

(c) SVD Approximation of rank 150

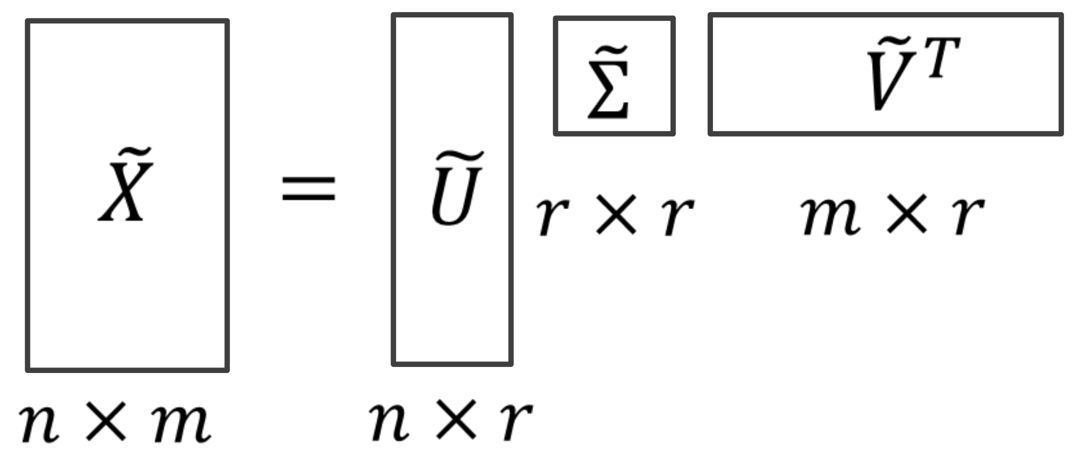
(d) SVD Approximation of rank 500

[5]

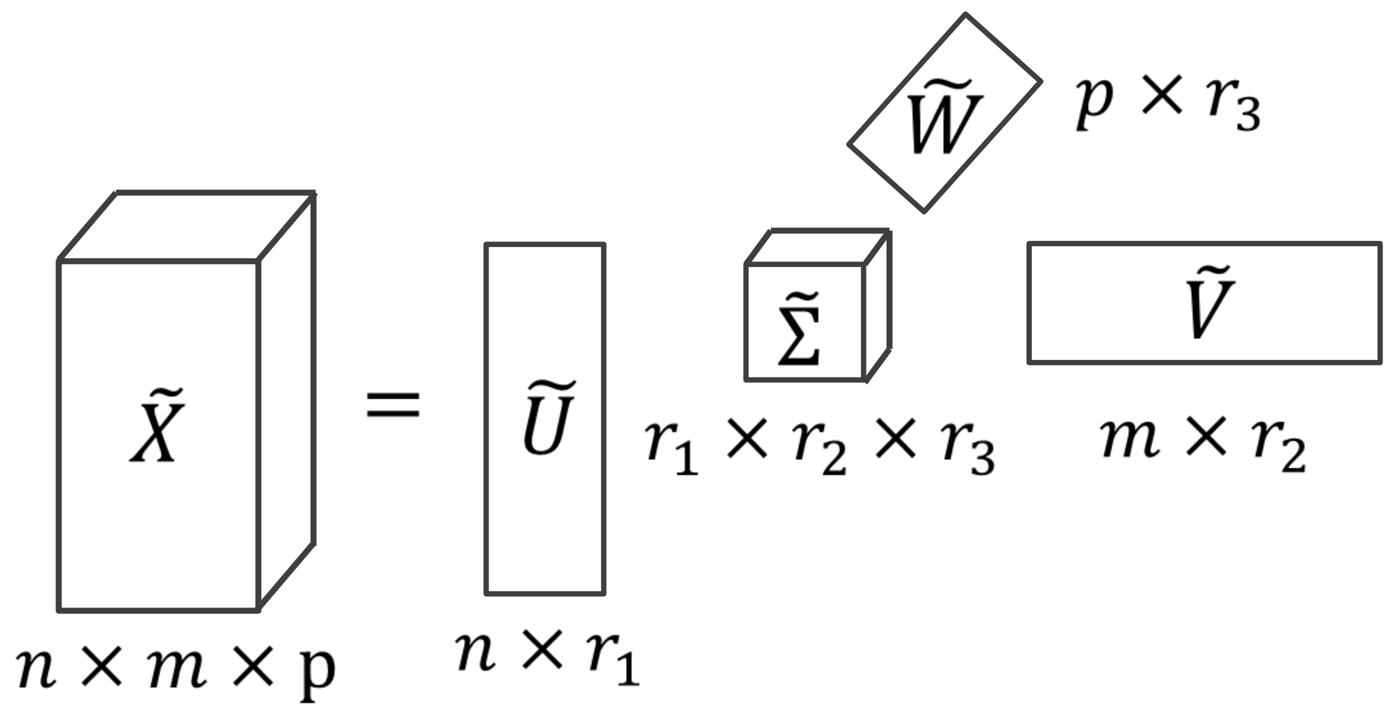
Funded by the European Union
HORIZON MSCA Doctoral Network, Project number 101072537

Reduced Order Model

SVD:



Higher-order SVD:

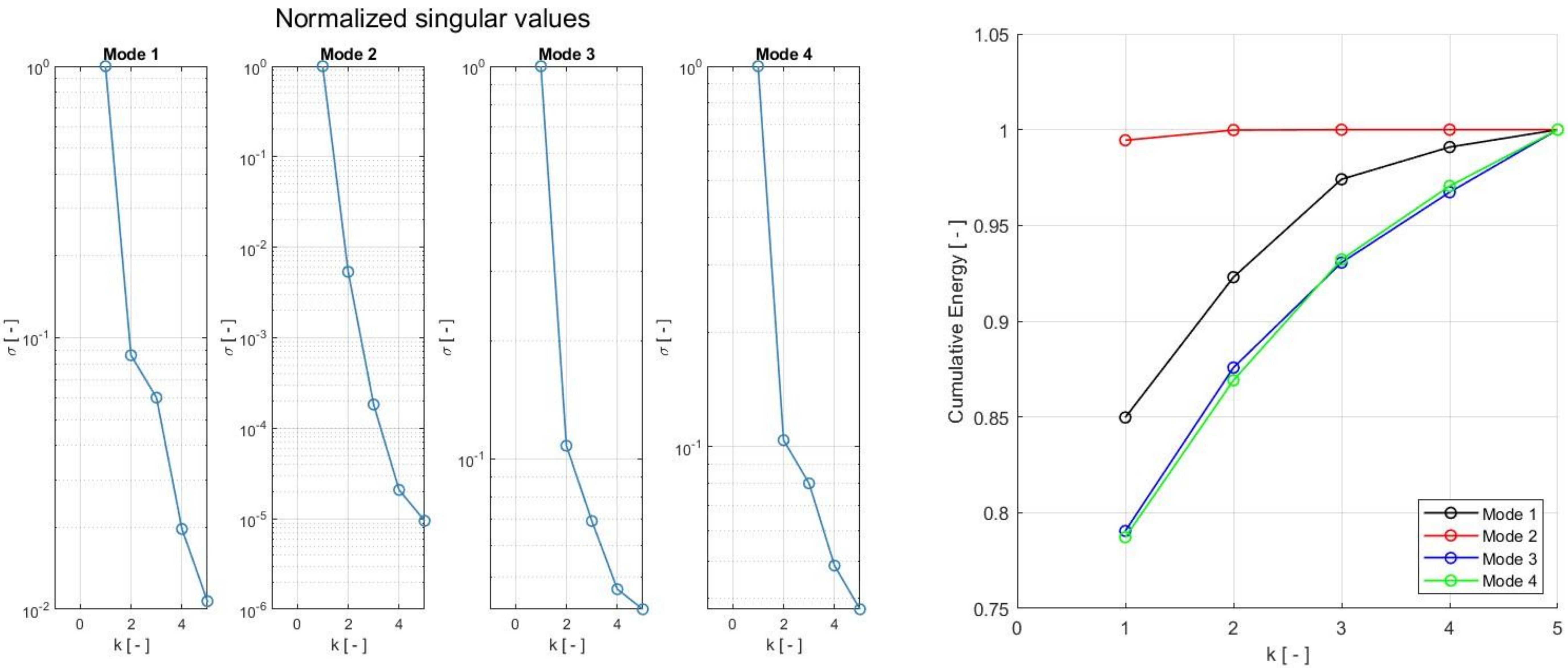


[6]

Funded by the European Union
HORIZON MSCA Doctoral Network, Project number 101072537

Reduced Order Model

- Uncoupled Reduced-Order-Model of Solugas-type cavity receiver



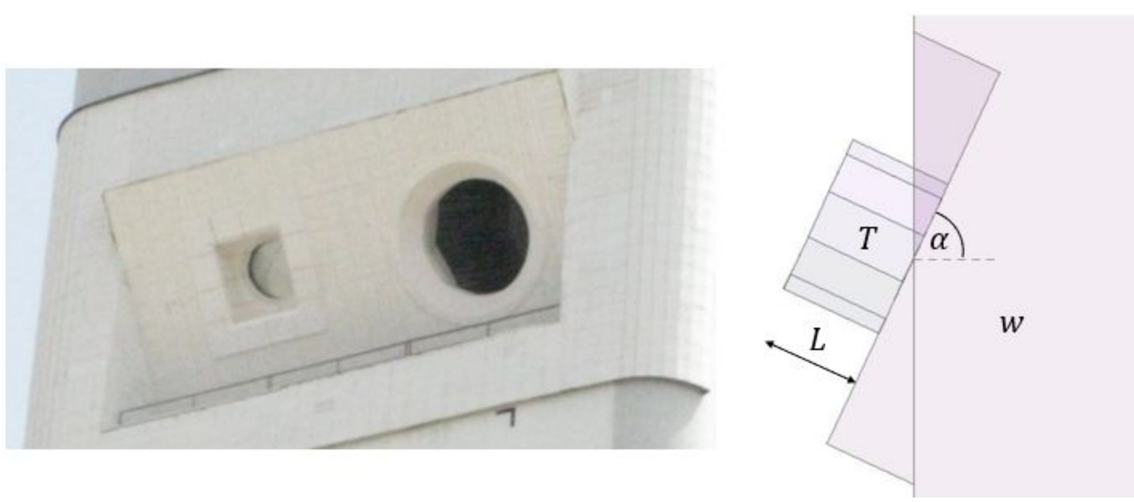
Funded by the European Union

Funded by the European Union

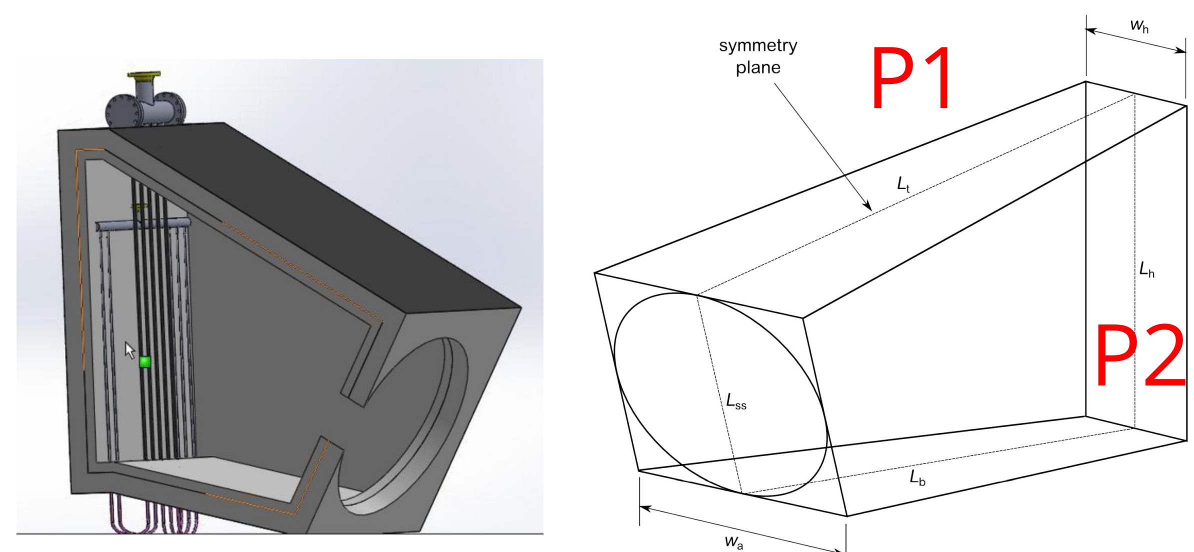
HORIZON MSCA Doctoral Network, Project number 101072537

Future work

- Using raytracing results as an import for both Solugas and Cersol ROM's (coupling)
- Consider P2: heat transfer to fluid
- Building a database for machine learning



Solugas receiver [3]



Cersol receiver [1]

Funded by the European Union

HORIZON MSCA Doctoral Network, Project number 101072537

TOP CSP

Funded by
the European Union

Towards, Competitive, Reliable, Safe and Sustainable Concentrated Solar Power (CSP) Plants

Midterm meeting REA, 18-19 April 2024

Thank you for your attention!

UNIVERSIDAD DE SEVILLA

VIRTUALMECH
KEEPING YOUR WORLD IN MOTION

References

[1] Virtualmechanics S.L., TRANSFER (2022), p.31 fig. 19, *Cersol cavity receiver*

[2] C. A. Domínguez Bravo, Optimization Models in solar power tower plants design (2015), p.61 fig. 2.12, *Valley region (Solar filed optimization)*

[3] Virtualmechanics S.L., TRANSFER (2022), p.52 fig. 44, *Photography of Solugas cavity receiver*

[4] S. Brunton, N. Kutz, Data Driven Science & Engineering (2017), p.5, *Singular Value Decomposition, Overview*

[5] C. Nuñez Fernández, Desarrollo y análisis de un modela de orden reducido POD con viscosidad artificial (2022), p.25 fig. 3.1, *Approximation of the original images with lower rank*

[6] L. R. Tucker, Some mathematical notes on three-mode factor analysis (1966), Psychometrika 31, p.279-311

Funded by the European Union

HORIZON MSCA Doctoral Network, Project number 101072537