

# Table of Content

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	First steps of the Entropy in history . . . . .	1
1.2	Porous Media Applied to Engineering . . . . .	4
1.3	Entropy Generation in the Literature . . . . .	5
1.4	Hypothesis and objectives . . . . .	9
1.4.1	Hypothesis . . . . .	9
1.4.2	General Objective . . . . .	9
1.4.3	Specific Objectives . . . . .	9
1.5	Overview of contributions . . . . .	9
<b>2</b>	<b>Transport phenomena in porous media</b>	<b>11</b>
2.1	Volume Averaging Method . . . . .	12
2.1.1	Time-average and spatial-average . . . . .	14
2.2	Transport equations for mass, momentum, and energy . . . . .	14
2.2.1	Continuity and Momentum equations . . . . .	15
2.2.2	Energy equation . . . . .	16
<b>3</b>	<b>1D Energy analysis of a porous heat exchanger</b>	<b>22</b>
3.1	Motivation . . . . .	22
3.2	Volumetric solar receiver design . . . . .	23
3.3	One dimensional analysis of a volumetric solar receiver . . . . .	24
3.4	Model Assumptions . . . . .	25

3.5	Theoretical model . . . . .	26
3.5.1	Continuity and momentum equations . . . . .	26
3.5.2	Fluid energy equation . . . . .	27
3.5.3	Solid energy equation . . . . .	27
3.5.4	Radiative energy transport in porous media as a participating media . . . . .	27
3.6	Boundary conditions . . . . .	29
3.7	Mesh Convergence Analysis . . . . .	30
3.8	Volumetric Goodness Factor . . . . .	31
3.9	1D Analysis Results . . . . .	31
3.10	1D Model Main Conclusions . . . . .	34
<b>4</b>	<b>Local entropy generation model for numerical CFD analysis of fluid flows through porous media, under laminar and turbulent regime</b>	<b>36</b>
4.1	Local Entropy Analysis . . . . .	37
4.2	Local entropy generation in turbulent share flows . . . . .	43
4.3	Entropy generation by turbulent dissipation and thermal dispersion for CFD . . . . .	44
<b>5</b>	<b>Numerical experiment: Study Case</b>	<b>48</b>
5.1	OpenFOAM® . . . . .	48
5.1.1	Development of <i>SgenPorousSimpleFoam</i> solver in OpenFOAM . . . . .	50
5.2	Case of study: 2D Porous Heat Exchanger . . . . .	53
5.2.1	System Description . . . . .	53
5.2.2	Boundary conditions . . . . .	54
5.3	Dimensionless Analysis . . . . .	55
5.4	Results and discussion . . . . .	57
<b>6</b>	<b>Conclusions</b>	<b>65</b>
6.1	Future Work . . . . .	66
	<b>Bibliography</b>	<b>75</b>

<b>Annex A</b>	<b>76</b>
A.1 General energy equation . . . . .	76
A.2 Spatial-averaging method on momentum equation . . . . .	77
A.3 Energy and entropy relation from Gibbs' equation . . . . .	78
A.4 Spatial-averaged transport equations for NTE porous media . . . . .	78
A.4.1 Continuity and momentum equations . . . . .	78
A.4.2 Energy equation . . . . .	79
A.5 Comparison factor $N_{Sgen}$ . . . . .	79