

Contents

List of Figures	xi
List of Tables	xiii
Acknowledgements	xiv
Abstract	xvi
Abbreviations	xix
1 Introduction	1
1.1 Objectives	2
1.2 Before the locomotive	3
1.3 Origins of the locomotive	4
1.4 Origins of the electric locomotives	6
1.5 Origins of Evacuated Tube Transport	7
1.5.1 Atmospheric railway	8
1.5.2 Pneumatic railway	11
1.6 Development of the magnetic train	14
1.7 Modern initiatives	16
1.7.1 Aeromovel	16
1.7.2 Maglev	17
1.7.3 Other initiatives	20
1.8 Development of electric air transportation	25
1.9 Hyperloop initiatives	25
1.9.1 Origin	25
1.9.2 Universities	26
1.9.3 Companies	27
1.9.4 Zeleros	29
1.9.5 Overview	31
1.10 Dynamic models	32
1.11 Thesis organization	33
2 Aerodynamic study of the capsule	35
2.1 Introduction	36
2.2 Materials and Methods	38
2.2.1 Geometry	38
2.2.2 Numerical domain	39
2.2.3 Mesh	40

CONTENTS

2.2.4	Set up	44
2.2.5	Inlet boundary condition	46
2.2.6	Specific set up for the compressor and nozzle	47
2.2.7	Knudsen number	49
2.3	Results	50
2.3.1	Mesh sensibility	50
2.3.2	Solver type	50
2.3.3	Inlet boundary condition	51
2.3.4	Flow behaviour for the <i>base</i> model	53
2.4	Discussion	57
3	Fanno model	65
3.1	Introduction	66
3.2	Numerical method	68
3.2.1	Numerical domain	68
3.2.2	Generic equations	69
3.2.3	Solution to Fanno equation	71
3.3	Results	73
3.3.1	Mesh independence	73
3.3.2	Validation with CFD	74
3.3.3	Critical length	79
3.3.4	Analysis of the equivalent diameter	81
3.3.5	No constant Reynolds analysis	83
4	Real-scale model	85
4.1	Introduction	86
4.2	Dynamic model	87
4.3	Aeropropulsive model	88
4.4	Thermodynamic cycle	91
4.4.1	Initial station	95
4.4.2	External channel solution	95
4.4.3	Internal flow solution	99
4.4.4	Rear expansion solution	102
4.4.5	Outputs	106
4.5	Non-thermodynamic modules	107
4.5.1	Geometry definition	107
4.5.2	System solver	111
4.5.3	Mass and Length solver	114
4.6	Loop closure	118
4.6.1	Inner loop definition	118
4.6.2	Optimisation and closure of net thrust	118
4.7	Results	119
4.7.1	Validation of the model with CFD	121
4.7.2	Parametric study	122

4.7.3	Optimisation	126
4.7.4	Reference vehicle	131
4.7.5	Comparison with other means of transportation	135
4.8	Future work	136
5	Middle-scale system	139
5.1	Introduction	140
5.2	Mission	141
5.3	Dynamic model	143
5.3.1	Physic problem	143
5.3.2	Integration scheme	144
5.4	Thermodynamic cycle	151
5.4.1	Upstream	152
5.4.2	Intake	153
5.4.3	External intake	154
5.4.4	Channel	154
5.4.5	External nozzle	155
5.4.6	Compressor	156
5.4.7	Transition	157
5.4.8	Duct	157
5.4.9	Nozzle	159
5.4.10	Downstream	161
5.5	Tube Thermodynamics	162
5.5.1	Steady term	163
5.5.2	Unsteady term	166
5.5.3	Full equation	167
5.6	Non-thermodynamic models	170
5.6.1	Forces	170
5.6.2	Battery discharge model	172
5.6.3	Commanded N	174
5.7	Tube ambient temperature model	175
5.8	Results	180
5.8.1	Mission profile	180
5.8.2	Tube thermodynamic variables	184
5.8.3	Internal thermodynamic variables	187
5.8.4	Component performance	189
5.9	Future work	191
6	Conclusions	193
6.1	Introduction	194
6.2	Aerodynamic study of the capsule	194
6.3	Fanno model	195
6.4	Real-scale system	196
6.5	Middle-scale system	198

References	199
A Fanno model	209
A.1 Development of ODEs	209
A.2 Equations for concentric circles	211
A.3 Friction factor	212
A.4 Fanno flow solution	212
B Real-scale model	215
B.1 Compressible continuity solver	215
B.1.1 Using static pressure	215
B.1.2 Using total pressure	215
B.2 Analytic solution for the choked channel	218
B.2.1 Choked in 15	218
B.2.2 Choked in 19	219
B.3 Cabin dimensions in <i>D-duct</i>	220
B.4 Computation of η_f and η_r	221
B.5 Optimisation plots	223
B.5.1 Z50 and 5-meter tube	223
B.5.2 Z50 and 6-meter tube	227
B.5.3 Z150 and 5-meter tube	230
B.5.4 Z150 and 6-meter tube	233