

Contents

Title page	i
Certificate of approval	iii
Certificate from supervisor	v
Dedication	vii
Acknowledgments	ix
Declaration	xi
List of figures	xviii
List of tables	xxi
List of symbols	xxiii
Abbreviations	xxvii
Abstract	xxix
Contents	xxxiii
1 Introduction	1
1.1 Preamble	1
1.2 Indian Railways	2
1.2.1 Safety performance	4
1.2.2 Locomotives	6
1.2.3 Locomotives nomenclature	7
1.2.4 Locomotive wheels	7
1.2.5 Braking of trains	9
1.2.6 Braking systems	11
1.2.7 Failure of railway wheels	13

1.2.8	Wheel gauge widening	15
1.3	Summary	18
1.4	Overview of thesis	18
2	Literature survey	19
2.1	Preamble	19
2.2	Friction and wear characteristics of brake blocks	19
2.3	Traction-slip characteristics	23
2.4	Running resistance	24
2.5	Time-lag in braking	26
2.6	Heat partitioning in tread braking	27
2.6.1	Temperatures in rolling/sliding bodies	27
2.6.2	Heat partition	28
2.6.3	Field measurements of wheel temperatures	30
2.7	Wheel residual stresses	32
2.8	Axle-wheel interference fit	35
2.9	Railway wheel deflection	35
2.10	Miscellaneous	37
2.11	Basis of objectives formulation	39
2.12	Objectives	39
2.13	Summary	40
3	Brake block characteristics and train running model	41
3.1	Preamble	41
3.2	Experimental procedure	41
3.3	Train running model	44
3.3.1	Governing equations	44
3.3.2	Time-lag in braking	46
3.4	Results and discussion	47
3.4.1	Brake block friction characteristics	47
3.4.2	Brake block wear characteristics	52
3.4.3	Traction-slip and running resistance characteristics	53
3.4.4	Train running analyses	54
3.5	Summary and conclusions	62
4	Estimation of heat partitioning and wheel temperatures	65
4.1	Preamble	65
4.2	Mathematical modelling	65
4.2.1	Heat partition analysis	66
4.2.2	Finite element analysis	70

4.3	Field trials	72
4.4	Results and discussion	73
4.4.1	Heat partitioning at wheel-brake block and wheel-rail interfaces	73
4.4.2	Heat generation during braking	78
4.4.3	Field studies	79
4.5	Summary and conclusions	85
5	Finite element modeling and identification of underlying mechanism for wheel gauge change	87
5.1	Preamble	87
5.2	Heat treatment and braking	88
5.3	Finite element modeling	88
5.4	Results and discussions	94
5.4.1	Wheel heat treatment	94
5.4.2	Locomotive wheel gauge change	99
5.5	Summary and conclusions	108
6	Effect of wheel profile, brake block type, and braking conditions on locomotive wheel gauge change	111
6.1	Preamble	111
6.2	Finite element modeling	111
6.3	Results and discussions	114
6.3.1	Heat dissipation rates in stop braking	114
6.3.2	Effect of wheel profile: Synchronized braking	114
6.3.3	Effect of brake block type: Independent braking	118
6.3.4	Effect of wheel profile: Independent braking	122
6.3.5	Wheel gauge change in drag braking	127
6.4	Summary and conclusions	128
7	Conclusions and future scope of study	131
7.1	Conclusions	131
7.2	Major contributions of this thesis	133
7.3	Future work	134
	Bibliography	134
A	Appendix: Coefficients appearing in Chapter 3	141
B	Appendix: Algorithm for $H(\tau)$ of Chapter 4	143