LIST OF CONTENTS

ACKNOWLEDGEMENT **I**

LIST OF CONTENTS **III**

LIST OF TABLES **VIII**

LIST OF FIGURES **XI**

LIST OF SYMBOLS **XIII**

PREFACE **XV**

CHAPTER 1: INTRODUCTION **1**

1.1 General Introduction 1
1.2 Optimisation 3
1.3 Newtonian Fluid and Non Newtonian Fluids 4
1.4 Motivation 5
1.5 Thesis Objectives 6
1.6 Organization of Thesis 7

CHAPTER 2: LITERATURE REVIEW **8**

2.1 Introduction 8
2.2 Review Based on Pipe Network Optimisation for Newtonian Fluid 10
2.2.1 Deterministic Optimisation Approaches 10
2.2.1.1 Analysis of Deterministic Optimisation Approaches 12
2.2.2 Evolutionary Algorithms (EA) 13
2.2.2.1 Genetic Algorithms 14
2.2.2.2 Differential Evolution (DE) 17
2.2.2.3 Analysis of Evolutionary Algorithms (EA) 17
2.2.3 Hybrid Optimisation Techniques 18
2.2.3.1 Analysis of Hybrid Optimisation Techniques 20

2.3 REVIEW BASED ON PIPE NETWORK OPTIMISATION FOR NON-NEWTONIAN FLUID 21
2.4 RESEARCH GAPS 25

CHAPTER 3: MATHEMATICAL MODEL 27

3.1 INTRODUCTION 27
3.2 KEY ELEMENTS 28
3.2.1 Search Space 29
3.2.2 Individuals or Chromosome or String 30
3.2.3 Genes 30
3.2.4 Fitness 30
3.2.5 Populations 31
3.2.6 Fitness Function 31
3.2.7 Coding 32
3.2.8 GA Operators 32
3.2.8.1 Selection 32
3.2.8.1.1 Roulette Wheel Selection 32
3.2.8.1.2 Tournament Selection 34
3.2.8.2 Crossover 34
3.2.8.2.1 Single Point Crossover 34
3.2.8.2.2 Two Point Crossover 35
3.2.8.3 Mutation 36
3.2.9 Penalty Functions 36
3.3 OUTLINE OF THE BASIC GENETIC ALGORITHM 37
3.4 IMPLEMENTATION OF GA ON PIPE NETWORK 40
3.5 SUITABILITY 41

CHAPTER 4: OPTIMISATION OF PIPE NETWORK FOR NEWTONIAN FLUID (WATER) USING GENETIC ALGORITHM 42

4.1 INTRODUCTION 42
4.2 DESIGN COMPONENTS 43
4.2.1 Objective function 44
4.3 CASE STUDY 46
4.4 APPLICATION OF GENETIC ALGORITHM FOR GESSLER (1985) PIPE NETWORK 50
4.4.1 Objective Function 50

4.4.1.1. Minimum Network Cost (z) 50
4.4.2.2. Penalty Cost 50
4.4.2.3. Constraints 51
4.4.2 Design Variables 51
4.4.2.1 Binary Coding for Commercially Available Pipes 52
4.4.3 Generation of Initial Population 54
4.4.4 Hydraulic Analysis of Network 55
4.4.5 Computation of Network Cost 56
4.4.6 Computation of Total Network Cost 56
4.4.7 Fitness 57
4.4.8 Generation of New Population Using Reproduction Operator 57
4.4.9 Crossover Operator 58
4.4.10 Mutation Operator 58
4.4.11 Computation of Network Cost Using Matlab Software 59
4.4.11.1 Convergence Study for Percentage of Cross over 59
4.4.11.2 Convergence Study for Mutation Rate 60
4.4.11.3 Convergence Study for Crossover Point 61
4.4.12 Results 65
4.5 CONCLUDING REMARKS 65

CHAPTER 5: OPTIMISATION OF PIPE NETWORK FOR NON-NEWTONIAN FLUID USING GENETIC ALGORITHM 66

5.1 INTRODUCTION 66

CASE-1 68

PIPE NETWORK CARRYING NON-NEWTONIAN FLUID (SLURRY WITH FINE PARTICLES) 68

5.2 THE TEST PROBLEM 68
5.3 IMPLEMENTATION OF GENETIC ALGORITHM 69
5.3.1 Objective Function 69
5.3.1.1 Friction Factor (f) 69
5.3.1.2 Reynolds Number (R) 70
5.3.1.3 Kinematics Viscosity (ν) 70
5.3.1.4 Drag Coefficient of Particle 70
5.3.1.5 Sediment Particle Reynolds Number 71

5.3.1.6 Fall Velocity (w) 71
5.3.2 Commercially Available Pipes 71
5.3.3 Average Roughness Heights 72
5.3.4 Design Variables 72
5.3.4.1 Lower and Upper Limit of Variables 74
5.3.4.2 Binary Coding for Commercially Available Pipes 75
5.3.4.3 Binary Coding for Roughness Height (€) 76
5.3.4.4 Chromosomes or String 76
5.3.5 Generation of Population 77
5.3.6 Minimisation of Objective Function 78
5.3.7 Computation of Network Cost Using Matlab Software 78
5.4 DISCUSSION AND CONCLUSION 81

CASE-2 82

PIPE NETWORK CARRYING NON-NEWTONIAN FLUID (SLURRY WITH COARSE PARTICLES) 82

5.5 THE TEST PROBLEM 82
5.6 APPLICATION OF GENETIC ALGORITHM 82
5.6.1 Objective Function 83
5.6.1.1 Head Loss Equation 83
5.6.1.2 Function of Concentration by Weight $f(CW)$ 83
5.6.1.3 Design Variables 84
5.6.1.4 Generation of Initial Population and Objective Function 85
5.6.2 Computation of Network Cost Using Matlab Software 85
5.7 RESULTS AND CONCLUSION 89
5.8 SOME OTHER OBSERVATIONS 89
5.8.1 Friction Loss versus Temperature of Fluid 90
5.8.2 Friction Loss vs. Volumetric Concentration (Cv) 91
5.8.3 Friction Loss vs. Average Flow Velocity (V) 92
5.8.4 Friction Loss vs. Diameter of Pipe (D) 93
5.9 DISCUSSION AND CONCLUSION 94

CHAPTER 6: VALIDATION OF GA SIMULATION RESULT ON EXISTING PIPE NETWORK 95

6.1 INTRODUCTION 95

6.2 FIELD NETWORK PROBLEM 96
6.3 FIELD VALIDATION 100
6.3.1 Instrumentation 100
6.3.1.1 Pressure Measurement Device 100
6.3.1.2 Discharge Measurement Device 101
6.3.2 Experimental Procedure 101
6.4 APPLICATION OF GENETIC ALGORITHM FOR AIT PIPE NETWORK 103
6.4.1 Objective Function 103
6.4.1.1 The Network Cost 103
6.4.1.2 Penalty Cost 103
6.4.1.3 Total Network Cost (z) 103
6.4.1.4 Constraints 104
6.4.2 Design Variables 104
6.4.2.1 Binary Coding for Commercially Available Pipes 105
6.4.3 Generation of Initial Population 107
6.4.4 Hydraulic Analysis of Network 107
6.4.5 Computation of Total Network Cost 109
6.4.6 Computation of Network Cost Using Matlab Software 109
6.5 RESULTS AND DISCUSSION 115

CHAPTER 7: CONCLUSIONS AND FUTURE SCOPE **116**

7.1 INTRODUCTION 116
7.2 CONCLUSION 116
7.3 FUTURE SCOPE 117

REFERENCES **118**

BUREAU OF INDIAN STANDARD CODES **130**

LIST OF PUBLICATION **131**

MATLAB PROGRAMMING **132**