# Table of Contents

Acknowledgements i  
Abstract iii  
List of Figures xii  
List of Tables xvi  
List of Symbols xx  
List of Acronyms xxiv  

## 1 Introduction 1  
1.1 Background 1  
1.1.1 Burr Formation 2  
1.1.2 Mechanism of Burr Formation in Drilling 4  
1.1.3 Burr Characterization 5  
1.1.4 Burr Shapes in Drilling 6  
1.1.5 Problems Associated with Burrs in Drilling 12  
1.1.6 Burr Removal Strategies in Drilling 13  
1.1.7 Key Observations 15  
1.2 Research Scope 16  
1.3 Thesis Outline 18  

## 2 Literature Review 20  
2.1 Parameters Affecting Burr Formation in Drilling 20  
2.2 Strategies to Minimize Burrs in Drilling 25  
2.2.1 Optimization of Process Parameters to Minimize Burrs 26  
2.2.2 Development of Finite Element Models to Reduce Burr Formation 29  
2.2.3 On-Line Monitoring of Burr Formation to Control Burr 32  
2.3 Meta Modeling Techniques 33  
2.3.1 Response Surface Methodology 33  
2.3.2 Fuzzy Logic 34  
2.3.3 Artificial Neural Network 35
2.3.4 Splines 35
2.3.5 Kriging 36
2.3.6 Radial Basis Functions 36

2.4 Multi Objective Optimization Methods 37
2.4.1 Genetic Algorithms 38
2.4.2 Simulated Annealing 38
2.4.3 Ant Colony Algorithm 39
2.4.4 Scatter Search Approach 39
2.4.5 Particle Swarm Optimization 40
2.4.6 Taguchi Robust Design 41

2.5 Observations from the Review of Literature 45

3 Research Objectives and Methodology 47
3.1 Research Objectives 47
3.2 Research Methodology 48

4 Experimental Procedure and Burr Size Measurements 52
4.1 Work Materials 52
4.2 Cutting Tools 53
4.3 Cutting Conditions 54
4.4 Machine Tool and Drilling Fixture 55
4.5 Burr Measurements 55
4.6 Experiments Based on Central Composite Design 58
4.6.1 Design of Experiments 58
4.6.2 Factors, Levels and Design Matrix for Central Composite Design 60
4.6.3 Experimental Results for Burr Size Based on CCD 61
4.7 Experiments Based on Orthogonal Array 63
4.7.1 Orthogonal Arrays 64
4.7.2 Factors, Levels and Orthogonal Array for Taguchi Design 64
4.7.3 Experimental Results for Burr Size Based on $L_9$ Orthogonal Array 65
7 Methodology of Taguchi Optimization for Multi-Objective Drilling

Problem to Minimize Burr Size

7.1 Robust Design – An Overview
   7.1.1 Robustness Strategy

7.2 Taguchi Robust Design Based Optimization

7.3 Taguchi Multi Objective Drilling Process Optimization
   7.3.1 Taguchi Approach with Utility Concept
   7.3.2 Taguchi’s Quality Loss Function Method
   7.3.3 Taguchi Approach with Fitness Mapping

8 Results of Drilling Optimization and Discussion

8.1 Results of Genetic Algorithms Optimization

8.2 Results of Taguchi Multi-Objective Optimization
   8.2.1 Results of Taguchi Approach with Utility Concept
   8.2.2 Results of Taguchi Approach with Quality Loss Function
   8.2.3 Results of Taguchi Approach with Fitness Mapping

8.3 Discussion on Multi-Response Taguchi Optimization

8.4 Comparison of Genetic Algorithms Optimization with Taguchi Multi-Response Methods

8.5 Key Observations from the Optimization Results of AISI 316L Work Material

9 Drilling Optimization of AISI 316L Work Material with Higher Drill Diameter Range – A Case Study

9.1 RSM with GA Optimization
   9.1.1 Development of RSM Models for Burr Size
   9.1.2 Analysis of the Parametric Influences on Burr Size
   9.1.3 Development of GA for Optimization
   9.1.4 Results of GA Optimization and Discussion

9.2 Taguchi Multi-Response Optimization
   9.2.1 Experimental Details
   9.2.2 Analysis and Discussion of the Experimental Results
10 Conclusions and Scope for Future Work
10.1 Conclusions 186
10.2 Scope for Future Work 190

References 191

Publications Related to Research Topic 217

Appendices 221
A Specifications of CNC Vertical Machining Center 221
B Specifications of Toolmakers' Microscope 222