Contents

Preface ix

Acknowledgements xi

1
Introduction 1
1.1 Introduction 1
1.2 What is design of experiments (DOE)? 2
1.3 Why design of experiments or statistically designed experiments? 3
1.4 Three approaches to design of experiments—classical, Taguchi and Shainin 4
1.4.1 Classical design of experiments 4
1.4.2 Taguchi methods 5
1.4.3 Shainin methods 6
1.5 Benefits of Taguchi DOE in manufacturing 7
1.6 Problems and gaps in the state of the art 13
Exercises 15
References 15

2
The Taguchi approach to quality improvement 17
2.1 Taguchi's definition of quality 17
2.2 Understanding variation 18
2.3 Measures of variation 20
2.3.1 The range, "R" 20
2.3.2 The standard deviation, "SD" 21
2.3.3 The mean deviation, "MD" 22
2.4 Variation and its influence on quality 23
2.5 Traditional and Taguchi's approach to quality loss functions 24
2.6 Determination of manufacturing tolerances 29
2.7 Other loss functions 31
2.7.1 Smaller-the-better quality characteristics 31
2.7.2 Larger-the-better quality characteristics 33
2.8 An example of Taguchi's loss function analysis 35
2.9 Taguchi's seven points of achieving quality 37

2.10 Taguchi's quality engineering system 39
2.10.1 On-line quality control system 40
2.10.2 Off-line quality control system 42
Exercises 45
References 45

3
The Taguchi approach to industrial experimentation 47
3.1 Traditional approach to experimentation 47
3.2 What are orthogonal arrays? 51
3.3 The role of orthogonal arrays 53
3.4 Linear graphs 56
3.5 Degrees of freedom 63
3.6 Randomization in industrial designed experiments 66
3.7 Selecting a standard OA for two-level factors 67
Exercises 70
References 71

4
Assignment of factor and interaction effects to an OA 73
4.1 Introduction 73
4.2 How to assign factor effects to an OA 74
Exercises 79
References 81

5
Classification of factors and choice of quality characteristics 83
5.1 Classification of factors in Taguchi's experimental design methodology 83
5.1.1 Control factors (x) 83
5.1.2 Noise factors (z) 86
5.1.3 Signal factors (M) 88
5.2 The role and contribution of noise factors in industrial experiments 89
5.3 Design for robustness—the key to improve product and process quality 90
5.4 Treating noise factors incorrectly 91
5.5 Taguchi's product array approach to experimentation 92
5.6 Choice of quality characteristics for industrial experiments 93
5.6.1 Examples of quality characteristics or responses 95
5.6.2 Multiple quality characteristics or responses 96
5.6.3 Quality characteristics for industrial experiments 100
Exercises 100
References 100

6
A strategic methodology for Taguchi design of experiments 103
6.1 Introduction 103
6.2 Devised methodology 104

6.3 Comments 115
Exercises 115
References 116

7
Problem classification 117
7.1 Introduction 117
7.2 Tools for the development of the problem classification framework 118
7.2.1 Understanding and analysing the process 119
7.2.2 Identification and investigation of the problem 119
7.2.3 Prioritization of problem causes 120
7.2.4 Problem classification 121
7.3 Problem classification framework 121
7.4 Generic problem source (GPS) 123
7.5 Problem selection framework (PSF) 126
7.6 Conclusions 132
Exercises 132
References 133

8
Metrology considerations for industrial experimentation 135
8.1 Introduction 135
8.2 Method of measurement 136
8.2.1 Direct method of measurement 136
8.2.2 Indirect method of measurement 136
8.2.3 Comparison method of measurement 136
8.3 Types of errors in measurements 136
8.4 Precision and accuracy 137
8.4.1 Precision 137
8.4.2 Accuracy 137
8.5 Properties of a good measurement system 138
8.6 The role of measurements in industrial experiments 139
8.7 Gauge repeatability and reproducibility 140
8.8 Planning gauge R&R studies 141
8.8.1 Procedure for conducting a gauge R&R study 142
8.8.2 Statistical control charts for analysing the measurement process variation 142
8.8.3 Analysis of results from R&R studies 145
8.9 Sampling variation in measurement system analysis 148
8.10 Environmental considerations for measurements 149
Exercises 150
References 150

9
Analysis and interpretation of data from Taguchi experiments 151
9.1 Introduction 151
9.2 Main and interaction effects 152

9.3 Determination of the statistical significance of the main and interaction effects 162
9.4 Signal-to-Noise ratio (SNR) 172
9.5 Relationship between the SNR and quality loss function (QLF) 174
9.6 When and how to use the SNR analysis 175
9.7 ANOVA for the signal-to-noise ratio 178
9.8 Determination of optimal process parameter settings 180
9.9 Estimation of the response at the optimal condition 182
9.10 Confidence interval for the estimated value 184
9.11 Confirmation run or experiment 186
9.12 Omega transformation 187
9.13 Conclusions 188
Exercises 189
References 193

10
Industrial case studies 195
10.1 Introduction 195
10.2 Case studies 196
10.2.1 Optimization of the life of a critical component in a hydraulic valve 196
10.2.2 Optimization of welding on cast iron using Taguchi methods 204
10.2.3 Reducing variability in transformer inductance through Taguchi methods 211
10.2.4 Optimization of machine performance using Taguchi methods 218

Appendices 225

Glossary 239

Index 247