Table of Contents

1. Introduction 1

2. Issues, Goals, and Methods of Flow Line Analysis 3
2.1 Variability and the Performance of Flow Lines 3
2.2 Non-Linearities in the Flow of Material 6
2.2.1 Assembly and Disassembly Operations 6
2.2.2 Split and Merge Operations and Rework Loops 8
2.3 Economic Design Problems in Flow Line Analysis 10
2.3.1 Cash-Flow Oriented Machine Selection and Buffer Allocation 11
2.3.2 Cash-Flow Oriented Buffer Allocation for a Given Set of Machines 20
2.4 Methods of Performance Analysis 22
2.5 Two-Machine Decomposition of Flow Lines 25
2.6 Review of the Literature 27

3. Assembly/Disassembly Systems with Random Processing Times 35
3.1 Discrete and Continuous Time Models 35
3.2 Exact Solution of a Two-Machine Subsystem 38
3.2.1 Performance Measures 40
3.2.2 Derivation of the Transition Equations 41
3.2.3 Identities 46
3.2.4 Derivation of the Solution 47
3.2.5 The Algorithm to Determine Steady-State Probabilities and Performance Measures 53
3.2.6 Determination of Performance Measures without Explicit Computation of all Steady-State Probabilities 53
3.2.7 Numerical Results for the Two-Machine Systems 56
3.3 Decomposition Equations for Assembly/Disassembly Systems 60
3.3.1 Conservation of Flow Equation 60
3.3.2 Flow Rate-Idle Time Equations 61
3.3.3 Resumption of Flow Equations 64
3.3.4 Interruption of Flow Equations 66

3.3.5 Simultaneous Solution of the Decomposition Equations . 71
3.3.6 Comparison with Jeong and Kim's Decomposition Equations for the Continuous Time Case 72
3.4 Two Algorithms to Determine Performance Measures 74
3.5 Numerical Results 76
3.5.1 Behavior of the Algorithm 76
3.5.2 Behavior of Assembly/Disassembly Systems 82
3.6 Optimal Design of Assembly/Disassembly Systems 86

4. Flow Lines with Rework Loops and Identical Processing Times 89
4.1 Discrete-Material Flow Line Model with Identical Deterministic Processing Times 89
4.2 Decomposition Equations for Loops and Identical Processing Times 91
4.2.1 Conservation of Flow Equation 91
4.2.2 Flow Rate-Idle Time Equations 92
4.2.3 Resumption of Flow Equations I: Split Operations 95
4.2.4 Resumption of Flow Equations II: Merge Operations ... 101
4.2.5 Boundary Equations 105
4.2.6 Simultaneous Solution of the Decomposition Equations . 105
4.3 The Algorithm to Determine Performance Measures 106
4.3.1 Purpose, Background, and Basic Structure of the Algorithm 106
4.3.2 Determination of the Evaluation Sequence 107
4.3.3 Initialization 108
4.3.4 Iterative Solution of the Decomposition Equations 109
4.3.5 General Comments on Implementation and Algorithm Behavior 114
4.4 Numerical Results: Algorithm and Flow Line Behavior 114
4.4.1 Introduction into the Numerical Study 114
4.4.2 Pure Split Structures 116
4.4.3 Pure Merge Networks 126
4.4.4 Structures with Loops 134
4.4.5 Summary of the Numerical Results 159
4.5 Optimal Design of Systems with Loops and Identical Processing Times 159
4.5.1 Impact of the Acceptance Probability at the Quality Inspection Station 160
4.5.2 Impact of the Placement of the Inspection Station 163

5. Flow Lines with Rework Loops and Machine-Specific Processing Times 165
5.1 Continuous-Material Flow Line Model with Machine-Specific Processing Times 165

5.2 Decomposition Equations for Loops and Different Processing Times 167
5.2.1 Conservation of Flow Equation 168
5.2.2 Flow Rate-Idle Time Equations 168
5.2.3 Resumption of Flow Equations I: Split Operations 169
5.2.4 Resumption of Flow Equations II: Merge Operations ... 173
5.2.5 Interruption of Flow Equations I: Split Operations 176
5.2.6 Interruption of Flow Equations II: Merge Operations ... 177
5.2.7 Simultaneous Solution of the Decomposition Equations . 180
5.3 The Algorithm to Determine Performance Measures 181
5.4 Numerical Results: Algorithm and Flow Line Behavior 183
5.5 Optimal Design of Systems with Loops and Different Processing Times 190

6. Conclusions and Suggestions for Further Research 195

A. Derivation for the Discrete Material Flow Line 199
A.1 Resumption of Flow Equations: Split System 199
A.1.1 Upstream Machine 199
A.1.2 Downstream Machine 211
A.2 Resumption of Flow Equations: Merge System 213
A.2.1 Upstream Machine 213
A.2.2 Downstream Machine in the Priority Two Line 215

B. Derivation for the Continuous Material Flow Line 225
B.1 Resumption of Flow Equations: Split System 225
B.1.1 Upstream Machine 225
B.1.2 Downstream Machine 228
B.2 Resumption of Flow Equations: Merge System 230
B.2.1 Upstream Machine 230
B.2.2 Downstream Machine in the Priority Two Line 231
B.3 Interruption of Flow Equations: Upstream Machine of a Split System 246
B.4 Interruption of Flow Equations: Merge System 254
B.4.1 Upstream Machine 254
B.4.2 Downstream Machine of the Priority Two Line 264

Glossary of Notation 273

Bibliography 275